TECHNICAL REPORT NO. LWL-CR-02P69

LISTENING POST SURVEILLANCE DEVICE (LPSD)
AN/PPS-14

Final Report
Contract No. DAAD05-69-C-0279

By

Aerospace Research, Inc.
130 Lincoln Street
Brighton, Massachusetts 02135

1971

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U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

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ABSTRACT

The Listening Post Surveillance Device (LPSD), AN/PPS-14, was developed to increase the target acquisition capability of combat riflemen under conditions of poor visibility, such as would be caused by intervening foliage, darkness, and inclement weather.

The development program started first with a shorter range CW radar system, but it rapidly evolved into a Pulsed Doppler system when the performance advantages and growth potential of such a system became apparent. The basic system operates at L-band, and the nucleus of the system is an adaptive and balanced signal processor which enables the radar to cope with a high clutter background while maintaining reliable target-detection performance.

Tests in Boston and Aberdeen as well as operational evaluation at Fort Hood and in Vietnam showed the radar to be an effective device for detecting targets up to 130 meters in open space, and approximately 30 to 100 meters in foliage depending upon density and wind velocity.

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LISTENING POST SURVEILLANCE DEVICE (LPSD)

1.0 INTRODUCTION

The Listening Post Surveillance Device (LPSD) was developed to increase the target acquisition capability of combat riflemen under conditions of poor visibility, such as foliage, darkness, and rainstorms. The specific objectives of the contract were to design, fabricate, and test a very lightweight, foliage penetrating radar to be carried and used by U.S. Army riflemen.

The basic system employs a L-band pulsed Doppler radar technique, and the nucleus of the system is a signal processor, both adaptive and balanced, which enables the radar to cope with moving foliage. Using this processing scheme, optimum detection; i.e. high detection reliability at a low false alarm rate, can be obtained under both high and low wind conditions.

The development of the LPSD was conducted using the following set of values listed in order of importance:

PERFORMANCE
RELIABILITY
DURABILITY
SIMPLICITY OF OPERATION
LOW COST
EASE OF MAINTENANCE

The performance criteria was based on achieving a large instantaneous coverage under foliated and wind conditions. A summary chart of performance target objectives and those that were achieved are shown in Table I.

In addition to achieving the target objectives for detecting a man walking or crawling in the brush, the LPSD can be used for detecting slowly moving vehicles, and river traffic. The maximum detection range is affected directly by the density and depth of foliage, and the wind velocity.

1.1 SIGNIFICANT IMPROVEMENTS

Two important improvements were introduced during the course of the contract. They were (a) a silent vibrating wrist alarm to avoid compromising the operator's position when annunciating a target detection, and (b) the transition of the system to pulsed Doppler with sensitivity time control (STC) to reduce false alarms from small near-in moving targets and, in general, provide greater system margins.

TABLE I

LPSD TARGET-DETECTION PERFORMANCE CHARACTERISTICS

Target Objectives	Achieved
Man Crawling: detection range under foliated conditions, 0-25 meters (50 meters desired) at rate greater than 0.1 m/s in a radial direction.	Approximately 30-40 meters depending upon foliage density and wing velocity. Approximately 50 meters in open space.
Man Walking: maximum detection range 75 meters (100 meters desired) of man walking at constant speed in radial direction at a rate greater than 0.2 m/s.	Approximately 30-100 meters depending upon foliage density and wind velocity. Approximately 130 meters in open space.
	Slowly moving vehicles, up to 160 meters.
	Small, low-profile water craft up to 100 meters.
Angular Coverage: Minimum $\pm 15^{\circ}$ from boresite.	130 meters range on boresite 125 meters range at $\pm 25^{\circ}$, 100 meters range at $\mp 45^{\circ}$, 50 meters range at $\mp 75^{\circ}$ 30 meters range at $\mp 90^{\circ}$

The wrist alarm is a vibrating alarm-indicator. When a target is detected, a motor within the wrist alarm drives an eccentric load, causing the vibration. In addition, target direction relative to the radar is indicated by means of solid-state lamps labeled "IN" and "OUT". An audio alarm output was also provided using a Sonalert device and a volume control. It also contains lights which indicates target direction (IN or OUT).

The principal feature of the pulsed Doppler system is that the receiver is turned off during the transmitting cycle, and therefore, nearby objects can be completely blanked out of the receiver or attenuated to any desired degree.

The advantages of a pulsed Doppler system are briefly outlined below.

1. Needs no special operator instructions on how to site the LPSD relative to local foliage. The system can be sited arbitrarily close to the foliage.

2. Largely eliminates false alarms due to operator motion, or vehicle motion in the backlobe of the antenna.

3. An RF amplifier can be used to improve the receiver noise figure. This results in increased dynamic range of the system.

4. Small animals, such as mice, will not alarm the system at short range.

5. The system can operate at a lower transmitting power level, which makes it less vulnerable to detection by enemy countermeasures systems.

6. The combination of STC and Sample-Hold gating permit shaping of the sensitivity vs range. For example, the sensitivity of the LPSD System increases (rather than decreases) with target range up to 50 meters. Beyond this zone, the sensitivity is governed by two-way space attenuation, groundlobing and foliage attenuation. The limit of detection is approximately 160 meters where the sensitivity of the system decreases abruptly.

1.2 DESIGN OBJECTIVES

This section contains the original design criteria and specifications established by LWL, both to serve as a point of departure, as well as to present an overview of the target design objectives in order to better follow the design changes that occurred during the execution of the contract. The final design parameters and specifications are included as part of Chapter 6.

The LPSD should be capable of achieving the detection distances shown in Table I over an arc subtending a horizontal angle of 30 degrees ± 10 degrees with the apex at the LPSD antenna. The LPSD should exhibit at least a 90% detection probability, and false alarms should not exceed 1 for every 4 hours of operation. Range and azimuth information to a target is desired, but not required.

The LPSD should contain its own antenna permitting horizontal polarization and should not require that it or the rest of the LPSD be elevated more than 1.5 meters (0.5 meters desired) above the ground in order to meet the requirements contained herein. If required, the LPSD should contain its own tripod. The antenna should exhibit a front-to-back ratio of 35 dB or better to disallow any false alarm detections caused by the operator or others moving anywhere behind the LPSD (within ± 90 degrees of the center line of the major horizontal lobe of the LPSD antenna as measured at the LPSD antenna). The antenna should be of such design as to concentrate the LPSD radiated energy into as small a vertical lobe as is necessary to meet the detection requirements. The antenna should be light, rugged, and compact as practicable.

The LPSD should be capable of a minimum of 12 hour continuous operation from a self-contained power source over the range of environmental and climatic requirements. The power source should be limited to two BA 1100/U batteries, Federal Stock Number 6135-926-0827. This is a 6.5 volt, 2.7 amp-hr (0.1 amp drain) mercury battery.

The LPSD should exhibit a minimum 95% reliability under operational conditions, and have a mean time between failure (MTBF) of at least 5000 hours.

The LPSD should require no other equipment to perform as specified herein.

The LPSD should not, from any aspect, be detected under a condition of total darkness beyond a distance of 10 meters by unaided human senses.

The operation of LPSD should not adversely interfere with the operation of radios and other electronic equipment normally found on the battlefield nor should the LPSD be adversely effected by such equipment.

The LPSD should be capable of withstanding the environment encountered in tactical long and short hauls associated with current U.S. Army land and air vehicles and U.S. Air Force air vehicles. The LPSD must withstand such operational environments without the protection of a transit case, securing straps, packing containers or other device or material designed to protect it from environmentally induced damage or malfunction.

The LPSD should be capable of meeting the performance requirements under specified temperature, climatic, and vibration conditions.

The LPSD should meet the performance criteria specified herein when operated by a typical, combat-equipped U.S. Army rifleman after no more than 30 minutes of on-the-job training. No calibration, sensitivity setting, or threshold control settings should be required.

The LPSD should be capable of full operation within 30 seconds or less after turn-on. Time required to emplace and turn on the LPSD should be less than 30 seconds. Time to turn off and displace the LPSD should be less than 30 seconds.

The LPSD visual alarm should be readable under all conditions of visibility.

The LPSD should be capable of annunciating a detection at a distance of 10 to 600 meters from its location by means of a wire connecting the LPSD to the LPSD Remote Annunciator (RA). The connecting wire should be U.S. Army Standard WD-1/TT general purpose field wire and should be provided as required by the Government. An RA unit should provide the same aural output and visual display as the LPSD unit.

The physical characteristics of the LPSD should be as close to the following as possible:

a. The total weight of the LPSD with power source, antenna and all other required components and assemblies, including the RA, should not exceed 5 pounds.

b. The volume of the LPSD with power source, RA, and all other required components and assemblies should not exceed 60 cubic inches.

c. The LPSD must operate at a nominal frequency of 1250 $\pm$ 5 MHz.

d. The LPSD should contain an external 3-position switch. One switch should be spring loaded. This switch should allow the operator to turn the LPSD on and off, and to self-test the LPSD.

e. The LPSD should contain a built-in test circuit and display device to monitor battery condition.

f. The LPSD should contain a self-test, go no-go circuit to inform the operator of any malfunction or deterioration

of any performance feature, especially detection capability. The test circuit should test all or as much LPSD circuitry as practicable. The self-test should be executed when the operator depresses the spring-loaded portion of the switch. The lamps used with the LPSD should exhibit an expected life of at least 1000 hours at a 95% confidence level.

g. The LPSD power supply/regulator should be short circuit proof. The LPSD should not contain a protective electrical fuse for this purpose.

The LPSD should be designed to include the following human engineering characteristics:

a. The night vision of the LPSD operator should not be adversely affected by the operation of LPSD during the hours of darkness.

b. The LPSD should permit simplicity in operation so that minimum training will be required for satisfactory operation and maintenance.

c. The LPSD should require a minimum of operator attention for normal operation. Operation of the LPSD should not induce undue operator fatigue.

2.0 PROJECT HISTORY

The project was started in March 1969. During the first month after the start of the LPSD development program, the target design requirements were reviewed and the Phase I Study Report was issued during April 1969.

On April 1, 1969, the LWL Contracting Officers Technical Representative visited ARI to review progress on the LPSD program prior to submission of the Phase I Study, and the Design Plan.

The block diagram of the breadboarded CW system was discussed. The basic parameters of the system were as follows:

Target Velocity	0.1 to 10 meters per second
Corresponding Doppler	0.6 to 60 Hertz
Transmitter Power	150 milliwatts
Received Signal range	0.1 to 17,000 microvolts for 10 to 100 meter range

The operational aspects of the LPSD were discussed, and the list that follows represents a system that was agreed upon to be the most desirable. This proposed system deviated from the system as defined by the contract, therefore, ARI had no authority to incorporate the changes. Any decision regarding these deviations was to be settled after submission of the Phase I reports. The changes that were discussed are as follows:

1. No loudspeaker for audio alarm. It was felt that the audio noise could give the operator's position away.

2. The loudspeaker could be replaced by an earphone, or preferably, a device such as a bone transmission annunciator. It was understood that one had been invented for the Red Eye missile system.

3. Separate incoming and outgoing detected target indicators would be provided. No switch was to be provided to select incoming only would be provided. In general, the absolute minimum number of controls on the panel was desirable.

4. There would be no "LATCH" function.

5. There would be no meter for battery status indication because:

    a. It is almost meaningless for mercury batteries,

b. Meter could not be seen at night without illumination which might give the operator's position away;

c. Meter is difficult to make watertight when submerged.

6. Battery test function will be included with the test and operate function switch. This switch will be the only switch on the front panel. Its four positions were to be:

OFF
TEST INCOMING
TEST OUTGOING
OPERATE

In the two test positions an extra load will be placed across the batteries. If either test fails, the operator should first change the batteries. If the test still fails, the operator should ascertain the specific problem.

The problems noted with the early ARI breadboard model were discussed. The biggest problems were large signal returns off the back radiation pattern of the antenna, and near-in clutter. It was stated that these problems might seriously restrict the usage of the LPSD. As for example, it might not be possible to mount the LPSD closer than 10 meters from the foliage. This confirmed earlier predictions that near-in targets would be a problem if a CW system was used.

At this point, the interrupted CW system was discussed as an alternate. The main benefit of this approach would be to blank out the LPSD for a range of 15 meters. This eliminates both problems mentioned in the previous paragraph, relieve many of the other problems, and permit the addition of a RF amplifier, which could result in increased battery life by reducing the transmitting power requirement.

The target identification capability of the ARI breadboard was demonstrated. No attempt at detection in a cluttered environment was made. The system demonstrated was the breadboard made on the precontract program along with an ARI balanced adaptive processor. Detection was always possible with no false alarms on incoming and outgoing targets. However, the system definitely indicated "found target" when the operator made unilateral movements one meter behind the antenna. Direction was correctly indicated when the operator made these movements, thereby substantiating the prediction that the CW system would detect operator motions off the back lobe of the antenna, despite the 35 dB front-to-back ratio.

The submission of the Phase I Study and the Design Plan was discussed. The reports were to include the following:

a. Phase I Report – to show results and conclusions. Any specifications that cannot be met should be called out along with recommended solutions.

b. Design Plan

1. Functional description of the unit
2. Block diagram and pertinent rough schematics
3. Sketches and conceptions
4. Schedule and milestones.

2.1 SUMMARY OF WORK UNDER PHASE I

The Phase I program, which was of four weeks duration, started with an analysis of the overall radar problem. This was done in order to see how the requirements of the contract influenced the individual parameters of the system, and to delineate those areas which appeared to be the most difficult, and hence deserving of early attention.

After performing the analysis, the breadboard radar equipment which had been put together during the course of an earlier company-sponsored program was modified to conform with the requirements shown by the analysis. A series of tests was performed. Although these tests were at a general sensitivity level which was of the order of 30 dB less than required, the tests sufficiently demonstrated the problems that would be encountered with the proposed CW system.

Sufficient data was obtained from the initial tests to determine the modifications that would be required to make the system functional.

2.2 FOLIAGE ATTENUATION

Foliage attenuation and clutter are the principal parameter influencing the design of the system, so a study was conducted to determine the effects on the overall performance of the system.

Figure 1 shows the average attenuation that would be experienced by a RF signal penetrating foliage as a function of frequency. This attenuation is an important consideration in a system of this kind because it must operate for sustained periods of time on small batteries. The amount of transmitted average power required depends directly upon the amount of foliage to be penetrated by the system.

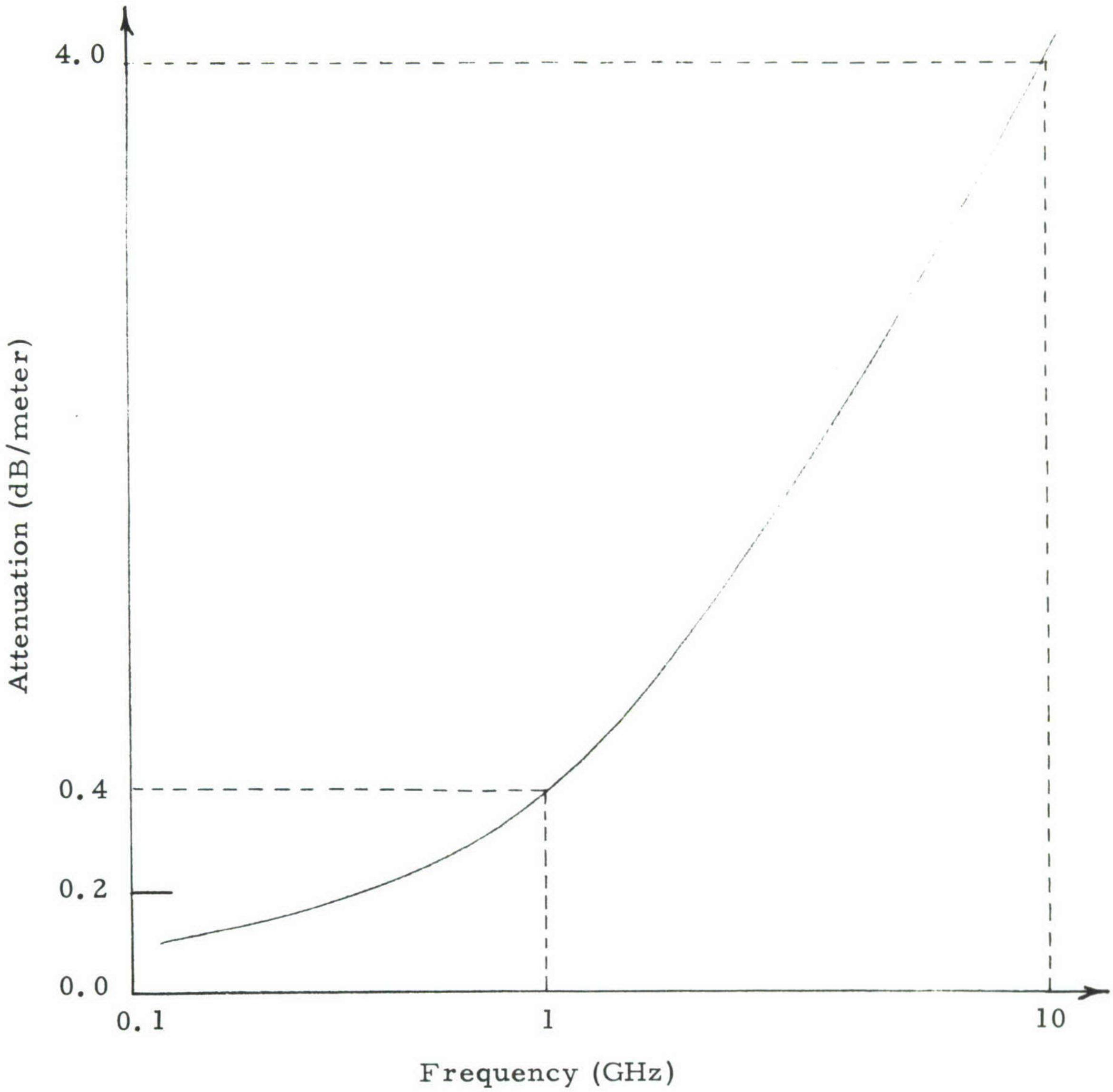


Figure 1: Average Dense Foliage Attenuation vs. Frequency

The curve shown represents the average attenuation of many foliage types, ranging from a dense New England forest to thick jungle. In practice, large deviations from the figures shown can be expected for a specific foliage type or density.

At 1250 MHz, the attenuation is approximately 0.5 dB/meter, which represents a total attenuation through 25 meters of foliage (two-way) of 25 dB. Fifty meters of foliage would introduce twice that amount (in dB).

It is possible to provide the system with a sufficient margin of sensitivity to make up for this kind of foliage loss, but it must be remembered that in a CW system, or for any very low range resolution system, this loss affects the dynamic range of the receiver and signal processor. A one square meter target at a range of 50 meters, for example, would be effectively 1,600,000 larger (+ 62 dB) than the same target observed at 100 meters through 50 meters of dense foliage, taking into account foliage and space attenuation. Similarly, the return signal from a section of foliage at 50 meters would be 1,600,000 greater than the same sample at 100 meters. This near-in foliage amplification relative to the 100 meter target greatly increases the system subclutter visibility requirements.

2.3 ANTENNA HEIGHT

When operating with an antenna which illuminates the ground as well as the target of interest, a well-defined ground reflection is produced. The constructive and destructive interference patterns produced by these two signals cause elevation lobes to be formed. Very little RF energy is present at ground level in the target area for horizontal polarization.

Because the lowest beam of the elevation lobing pattern is the one which illuminates the target of interest, the energy distribution in that lobe is of great importance. Figures 2 and 3 show the positions of the peak of the first lobe at 1250 MHz. The peaks exhibit a two-way gain of + 12 dB above free space gain. It can be seen from Figure 3 that an antenna height of approximately 1.5 meters is required to illuminate the head of a walking man at 75 to 100 meters. This same antenna height would provide free space gain on the head of a crawling man at a range of 12 to 25 meters.

2.4 SENSITIVITY REQUIREMENTS - CW SYSTEM

As stated previously, the target signal amplitude at the input to the receiver will vary considerably as a function of range and foliage absorption. Of prime interest is the minimum return signal amplitude, since this will permit determination of radiated power requirements and permissible receiver noise figures.

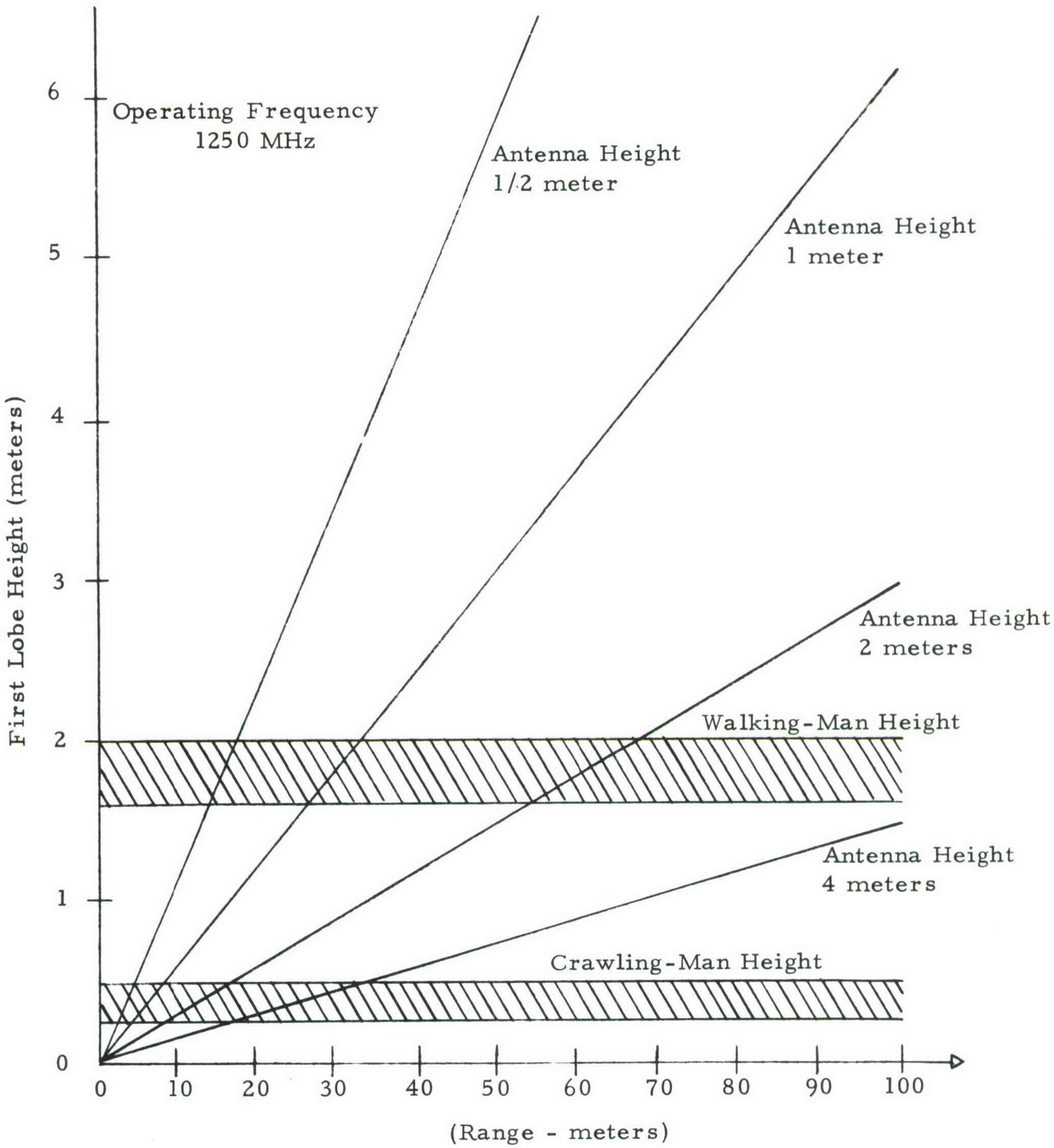


Figure 2: First Lobe Height vs. Range for Various Antenna Heights

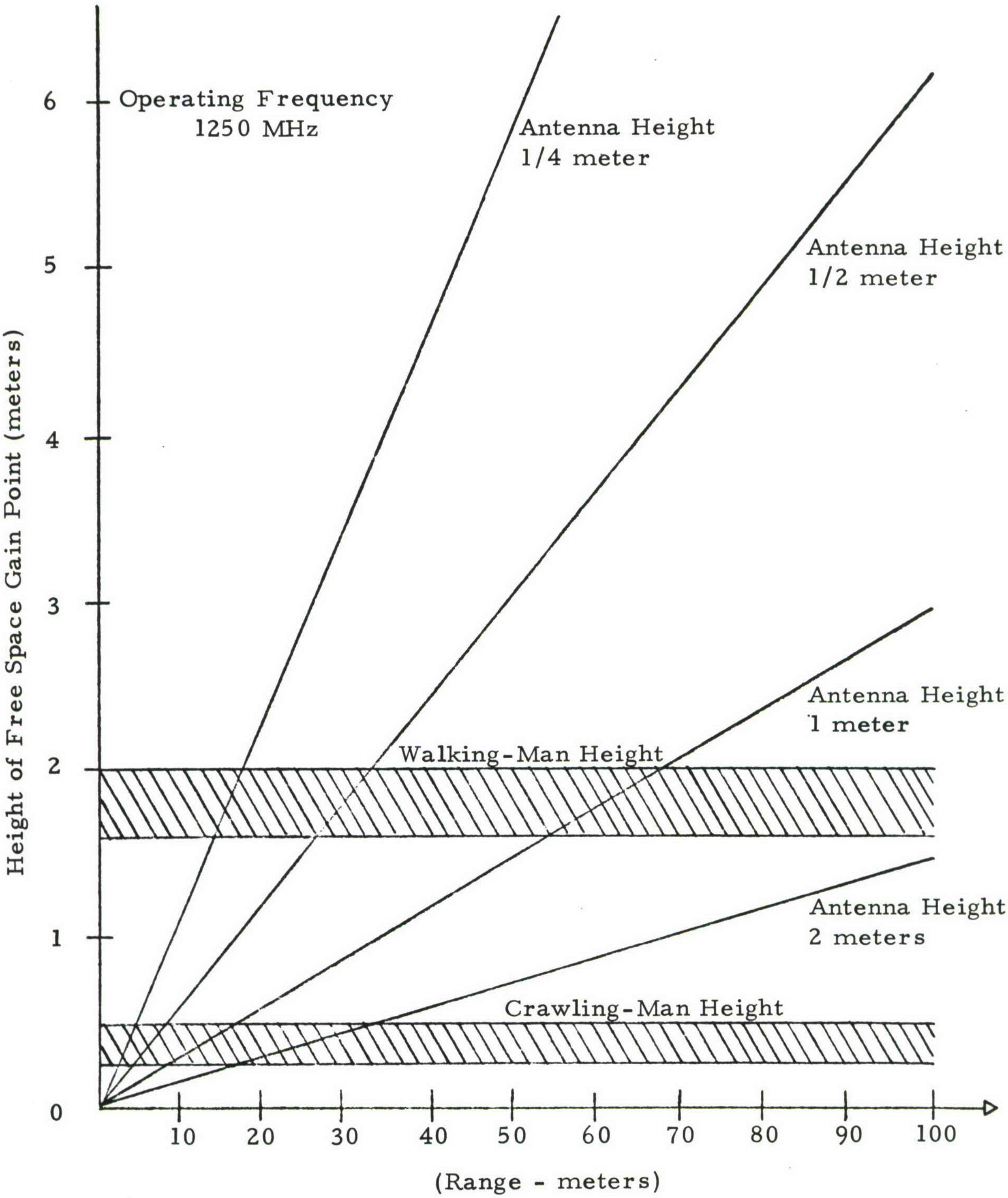


Figure 3: Height of Free Space Gain Point vs. Range

A minimum return signal analysis was performed on a CW radar with the following characteristics:

Radiated Power	150 mW
Desired Range	100 meters
Surveillance Coverage	40 degrees
Vertical Antenna Beamwidth	30 degrees
Carrier Frequency	1250 MHz
Doppler Return Frequency	$\pm$ 0.5 to 60 Hz
Cross-section of Upright Human	1/2 meter^2
Antenna Height	1.5 meters

The minimum return signal, S_{min}, was calculated using the following form of the radar equation:

$$R = \sqrt[4]{\frac{\overline{P}\, G\, A_e \sigma}{(4\pi)^2\, S_{min}}} \qquad \text{Range (meters)} \qquad (1)$$

where:

$\overline{P}$ = Average radiated power = 150 mW

G = Free Space Antenna Gain = $\dfrac{4\pi 3600}{\theta_1\, \theta_2}$ = 37.7

A_e = Antenna Aperture = $\dfrac{G\lambda^2}{4\pi}$

λ = Wavelength = 0.24 meters

σ = 1/2 meter^2

Rearranging equation (1) and solving for S_{min} gives

$$S_{min} = \frac{\overline{P}\, G^2 \lambda^2}{(4\pi)^3\, R^4} \qquad \text{(watts)} \qquad (2)$$

Substituting the values of the system being considered into equation (2) yields the following value for

$$S_{min} = 37.1 \times 10^{-12} \text{ watts}$$

$$= 42 \text{ microvolts into a 50 ohm load.}$$

The number above represents the minimum signal captured by the antenna for a 100 meter path with no intervening foliage. Of prime interest is the worst case signal present at the output of the RF section when the foliage attenuation is 50 dB (50 meters of foliage). The other losses associated with the system as well as the path loss are tabulated below.*

Antenna Hybrid	3.5 dB
Zero Degree Hybrid	3.5 dB
Dual Mixers	9.0 dB
Foliage Penetration Loss	50 dB
Miscellaneous Losses	4 dB
Total System Loss	70 dB

Adding these losses to S_{min} calculated above gives the minimum signal that will be present at the input to the audio amplifiers, or

$$S_{min} \text{ out of mixers } = 37.1 \times 10^{-19} \text{ watts}$$

$$= 14 \times 10^{-9} \text{ volts.}$$

The noise associated with the input of the receiver was computed for a 50 ohm input using the standard equation for thermal noise.

$$\text{Noise Power} = KTB \tag{3}$$

and

$$\text{Noise Voltage} = \sqrt{KTBR} \tag{4}$$

*Refer to Figure 4 for a block diagram of the system.

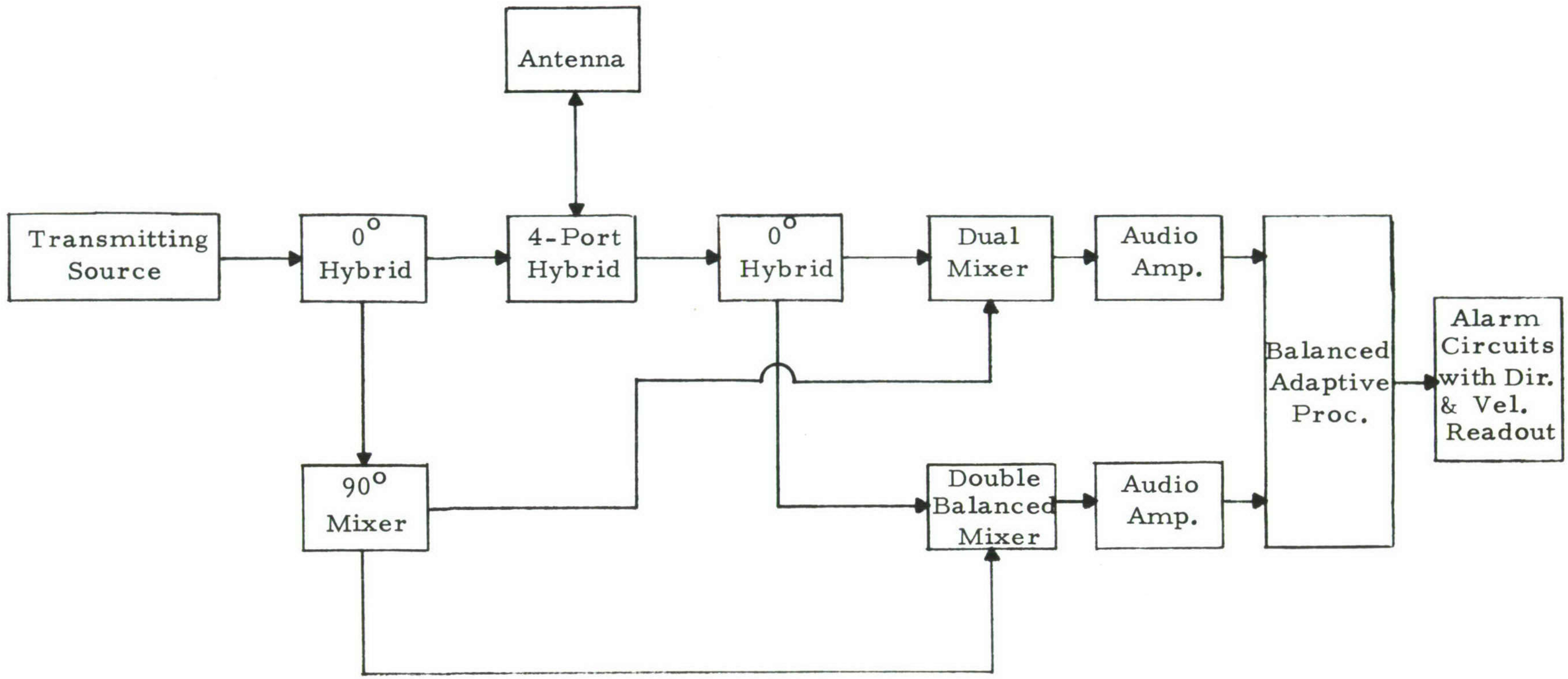


Figure 4: LPSD CW Breadboard

where

K = Boltzman's constant = 1.38×10^{-23} watt-sec/^{o}K

T = 290^{o}K (Room temperature)

B = 60 Hz (Bandwidth of audio amplifiers)

R = 50 ohms

Substituting these values into equation (4) yields a noise voltage of 3.5×10^{-9} volts. This is 12 dB less than the minimum amplitude of the return signal.

An examination of the noise of the audio amplifiers referred to the output of the mixers indicates that this noise is far worse than that of the 1250 MHz noise calculated above. The worst component is the 1/f noise. Measurements indicate that an equivalent noise of less than 150×10^{-9} volts would be very difficult to obtain.

Some improvement can be obtained in the magnitude of the received signal by matching the low impedance output of the mixers to the high input impedance of the audio amplifiers by a good sub-audio transformer. The minimum input signal to the audio amplifiers can be increased to 280×10^{-9} volts by this method. The resulting 6 dB increase in signal to noise ratio is adequate for signal detection, particularly after further improvement is possible by post-detection filtering in the processor by an additional 6 dB.

There was a considerable reduction in signal margin when the allocated frequency was changed to 1250 MHz from the original asked for 915 MHz. It is estimated that this change reduced the minimum signal at the output of the mixers by 10 dB. Under these conditions the maximum return signal from near-in jungle foliage at, for example, 10 meters, would be of the order of 1 millivolt at the mixer output. This requires that the system have a dynamic range of approximately 100 dB.

2.5 TEST RADAR

A block diagram of the breadboard radar used to perform the preliminary tests is shown in Figure 4. RF is supplied by a 900 MHz, 60 milliwatt power source. 30 milliwatts are required for the dual mixers, and 15 milliwatts was radiated, taking into account hybrid losses of approximately 3 dB.

The receiver portion of the antenna hybrid connects to a zero degree hybrid which in turn feeds a pair of doubly-balanced mixers with equal amplitude and equal phase signals. Local oscillator signals are fed into the mixers through a ninety degree hybrid. The

quadrature audio signals out of the hybrids are supplied to low-noise audio amplifiers, and subsequently to the signal processor. The processor used for most of the experiments was an ARI Series AB-1100, Balanced Adaptive Processor.

2.6 TESTS

The first series of tests were conducted in the laboratory. These were concerned primarily with the effects of oscillator noise and instability, and quadrature unbalance in the system as well as the degree of transmitter isolation that could be obtained through the hybrid and antenna system. It was concluded that the local oscillator noise level could be kept below a point where system performance would not be effected. Good quadrature balance was possible but only after the RG-58/U coaxial cables with BNC connectors were replaced by semi-rigid coaxial cables with OSM connectors. Although good isolation was attainable in the antenna hybrid, it was affected by objects moving in the vicinity of the antenna.

A number of experiments were made on personnel moving within the building, primarily as a check on the basic operation of the system against moving targets. It was interesting to note that moving people would be reliably detected two rooms away, through wooden walls at a range of about 15 meters. Longer range experiments of this kind were not tried, but it was clear that the system had substantial margin at this range when targets were detected through the walls.

The antenna was pointed out of a second story window toward the Massachusetts Turnpike. Vehicles moving along the turnpike at a range of 100 meters could be observed despite the fact that the system had 30 dB less sensitivity than that required in the final system.

A series of experiments were also conducted against controlled targets and targets of opportunity in the ARI parking lot. It was during these experiments that it was clearly shown that despite the 35 dB backlobe (70 dB, two-ways) of the antenna used, the motion of the operator behind the antenna generated a significant amount of noise in the unit, and in some cases, false alarms. Although the balanced processor cancelled out a major portion of the operator's back and forth motion, the system false-alarmed when the operator moved unidirectionally with respect to the radar. This problem was present even though the system was 30 dB short of the design goal.

A short series of experiments was conducted in an area of evergreen trees. The system had no trouble detecting targets behind several evergreens, even when the wind was blowing. It was clear from these experiments, however, that adaptive filtering was required. When the filters were tuned to a lower frequency to allow detection of targets moving at the rate of 0.1 meter/second, the

clutter level, particularly under higher wind conditions, was too high for the system to handle. Under these conditions, the small amount of filter adaption that did take place allowed the system to function normally.

2.7 PHASE I DESIGN CONCLUSIONS

Nothing was uncovered during the course of Phase I investigations that would indicate that a system very close to the one originally proposed would not meet most of the specifications outlined in the contract. There were some uncertainties as to whether a man crawling at the rate of 0.1 meter/second could be detected except under very low wind conditions, or that the size of the radar package could be contained within the 60 cubic inches specified.

There were sufficient basic weaknesses associated with the CW system to warrant a change to an interrupted CW (ICW) mode of operation. The basic weaknesses of the CW system are as follows:

1. A CW system operating in a high dynamic range environment will always be subject to false alarms due to operator movement. False alarms will also be frequent from vehicles in back lobe or side lobes of the antenna radiation pattern.

2. A CW system may be subject to false alarms due to very small targets, such as a frog, moving in the main beam close to the antenna.

3. Because of maximum dynamic range and subclutter visibility considerations, the system will be subjected to severe restrictions with regard to the nearness of the antenna to the foliage. It might be necessary, for example, to be sure no high grass is anywhere near the antenna, and that the jungle interface occurs at a range greater than 15-20 meters.

To solve the problems outlined above, an interrupted CW (ICW) scheme was configured. The main feature of the ICW system is that the receiver is shut off during transmit, and nearby objects, as far out as 10 meters if desired, may be completely blanked out of the receiver. The advantages of the ICW system are tabulated as follows:

1. No special siting instructions are required relative to local foliage.

2. False alarms are largely eliminated due to operator motion or vehicular traffic in the backlobe of the antenna.

3. An RF amplifier can be used to improve the receiver noise figure. This cannot be done with a CW system because increased signal level would cause saturation in the mixers. The resulting increased sensitivity may permit a large reduction in average radiated power, thereby providing increased battery life.

4. Small animals, such as mice, will not alarm the system at short range.

5. The system can operate at a lower transmitter power level, which makes it less vulnerable to enemy detection.

The ICW technique was further improved by combining the audio amplifier with a sample and hold circuit. The combined use of a RF amplifier, STC (sensitivity time control), and sample and hold circuits largely eliminates the problems encountered in CW systems.

The system, in its present form, can best be characterized as a high repetition rate, long pulse radar system. Since it utilizes sample-hold circuits and performs range gated Doppler filtering, it will be referred to as a pulsed Doppler system.

3.0 DESIGN CONSIDERATIONS

Due to the obvious advantages of the pulsed Doppler radar system established under the Phase I study and subsequent tests of the breadboard model, ARI formulated a design plan based on this approach. The main features and the advantages of such a system were discussed in the previous chapter.

A tabulation of the existing characteristics of the LPSD system is shown in Table II. The characteristics outlined in this table will be used as a point of departure for discussing the design parameters for the system.

3.1 SENSITIVITY REQUIREMENTS-PULSED DOPPLER SYSTEM

The sensitivity requirements for the revised pulsed Doppler radar system were made using the parameters shown in Table I and the following:

λ = 0.24 meters (Wavelength)

σ = $0.5 m^2$ (Cross-section of upright man)

R = 100-500 m (Distance to target)

3.1.1 RECEIVED SIGNAL OF LPSD AT DIFFERENT RANGES

The minimum return signal for different target ranges was computed using the following form of the radar equation;

$$S_{min} = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 \; R^4} \quad \text{(watts)} \tag{5}$$

where the terms and values were stated previously. The minimum detectable signal S_{min}, which appears in the radar equation, is a statistical quantity and must be described in terms of detection and the probability of a false alarm. For average reception, the signal to be reliably detected must be larger than noise (generally by 10-20 dB) at the point in the receiver where the detection decision is made.

The voltage can be determined by assuming a 50 ohm system, and by converting power to voltage as follows:

$$V = \sqrt{S_{min} R} \tag{6}$$

TABLE II

LPSD CHARACTERISTICS

Transmitter Frequency	1250 MHz $\pm$ 5 MHz
Transmitter Peak Power	30 mW
Transmitter Average Power	10 mW
Pulse Width	600 nanoseconds
Repetition Rate	220 kHz $\pm$ 15%
Antenna Type	Simulated parabolic antenna with 4" focal length
Horizontal beamwidth	72 degrees min.
Vertical beamwidth	46 degrees max.
Gain	Approximately 10 dB
Height above ground	1.5 meters
Receiver	Quadrature video, homodyne
Power Requirements	$\pm$ 6 volts @ 150 mA each
Normal Battery Life	12 hours
Max. Personnel Detection in Foliage	30-100 meters depending upon density
Max. Personnel Detection in Clear	130 meters
Foliage Penetration Capability	25-50 meters, depending on density and wind
Weight	8 lbs. 12 oz.
Volume	252 cubic inches
Receiver Dynamic Range	100 dB
Controls	Power On/Off, Test Outgo/Test Incom
Remote Display	Tactile Stimulator, Outgo/Incoming Visual Indication

where R is assumed to be 50 ohms.

The minimum return signal power and voltages for various ranges are tabulated in the table below:

R (m)	S_{min} (W)	V (microV rms)
100	1.45×10^{-13}	2.69
150	2.87×10^{-14}	1.2
250	3.72×10^{-15}	0.43
500	2.32×10^{-16}	0.11

3.1.2 GAIN OF PULSED DOPPLER SYSTEM

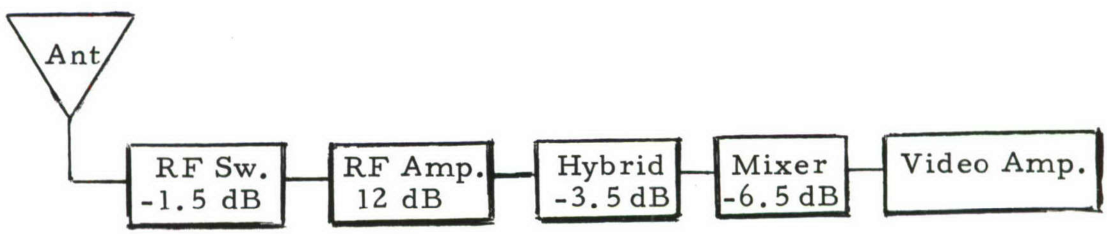
The net gain of the LPSD is based on the following circuit gains and losses:

Unit	Gain/Loss (dB)
Signal Processor	96
Video Amplifier	36
RF Switches	-3.5
0° Hybrid	-3.5
Mixers	-6.5
RF Amplifier	12
Total Gain	130.5

Assuming 3.0 V p-p (1.0 V rms) is required at the input to the final threshold circuit, the minimum voltage required is 0.3 microvolts rms.

3.1.3 SYSTEM NOISE FIGURE

The system noise figure computed for the pulsed Doppler system was based on the following block diagram:



The total system noise for a N-component cascade is given by the expression:

$$T_s = T_a + \sum_{i=1}^{N} \frac{T_e(i)}{G_i} \quad (^oK) \tag{7}$$

where

T_s is the total system noise temperature,

T_a is the antenna noise temperature,

$T_e(i)$ is the effective input noise temperature of the i^{th} component,

G_i is the available gain of the system between the input terminals of the i^{th} component in the cascade.

The expression above shows that the noise temperature of a given component is amplified or decreased by the total gain of the system preceding that component. It will be used to compute the final noise temperature of the system after the component noise temperatures have been computed.

3.1.4 ANTENNA NOISE TEMPERATURE

The antenna noise temperature is assumed to be 200^oK.

3.1.5 NOISE TEMPERATURE OF RF SWITCH

The noise temperature can be computed from the following expression:

$$T_e = T_o (L - 1) \tag{8}$$

where L is the loss factor of the switch (1.5 dB) expressed as a power ratio. Substituting the loss factor into equation (8) and recalling that T_o is the absolute temperature at room temperature (290^oK),

$$T_e = 290 (1.413 - 1)$$

$$T_e = 129^oK.$$

3.1.6 NOISE TEMPERATURE OF RF AMPLIFIER

The noise figure of the RF amplifier is assumed to be 7 dB. Noise figure can be converted to noise temperature by the following expression:

$$T_e = T_o (F_n - 1) \tag{9}$$

where F_n is the noise figure expressed as a power ratio. Substituting the values into equation (9) gives

$$T_e = 290 (5.01 - 1)$$

$$T_e = 1163^o K$$

3.1.7 NOISE TEMPERATURE OF HYBRID

The hybrid losses are assumed to be 3.5 dB, therefore, $T_e = 331^o K$ as determined from equation (8).

3.1.8 NOISE TEMPERATURE OF MIXER

The mixer noise figure is assumed to be 7.0 dB. This yields a noise temperature of $1163^o K$ when the noise figure is substituted into equation (9).

3.1.9 NOISE TEMPERATURE OF VIDEO AMPLIFIER

The noise figure F_n, of the video amplifier was calculated for Fairchild's Linear Integrated Circuit μ A 733c. The input noise is typically 12V rms for R_s = 50 ohms, and the bandwidth BW is equal to 1 kHz to 10 MHz. The noise at the input, therefore is:

$$\text{Noise at Input} = \frac{E^2}{R}$$

$$= 2.9 \times 10^{-12} \text{ watts } (-85.4 \text{ dBm})$$

The thermal noise at room temperature ($290^o K$) was computed from the expression KTB, where K is Boltzman's constant (1.38×10^{-23} watt-sec/$^o K$), T is the temperature in $^o K$, and B is the bandwidth in Hz (10 MHz for LPSD). Evaluating the expression for KTB using the values specified, gives – 104 dBm as the thermal noise power of the video amplifier.

The noise figure can be obtained from the following:

$$F_n = \frac{\text{Noise at Input}}{\text{Thermal Noise}} \tag{10}$$

or $F_n = -85.4 + 104 = 18.6$ dB

or in terms of noise temperature,

$$T_e = 290^{\circ}(72.4 - 1) = 20,706$$

It can be seen that the video amplifier is the largest contributor of noise in the system.

3.1.10 TOTAL SYSTEM NOISE

Total system noise can be computed by inserting the noise temperature values found for the various components into equation (7). The total noise temperature for N-components is tabulated below.

Component	T_e ($^{\circ}$K)	G_i(dB)	$T_{s(i)}$($^{\circ}$K)
Antennas	200	0	200
RF Switch	120	0	120
RF Amplifier	1163	1.5	1640
Hybrid	331	-11.5	23
Mixer	1163	-7	232
Video Amp.	20,706	-0.5	18,500
		Total	20,715

The systems noise figure is therefore:

$$\text{Systems Noise Figure} = \frac{20,715}{290} = 71.5 \quad (18.5 \text{ dB})$$

3.1.11 SIGNAL/NOISE CALCULATIONS

The signal to noise ratio for a single pulse return is given by,

$$S/N = \frac{P_t \tau G^2 \lambda^2 \sigma}{(4\pi)^3 \; KTLR^4} \tag{11}$$

where

P_t	=	10 mW	(Transmit power)
τ	=	600 ns	(Pulse duration)
G	=	10 dB	(Antenna gain)
λ	=	0.24 m	(Wavelength)
σ	=	$1\ m^2$	(Target cross-section)
K	=	1.38×10^{-23}	(Boltzman's constant)
T	=	$20,715\ ^oK$	(System noise temperature)
L	=	3.0 dB	(Transmission loss)
R	=	150 m	(Range)

Substituting the above values into equation (11) yields a value for signal to noise ratio equal to -12.1 dB (in free space).

3.2 SYSTEM GAIN/LOSS FACTORS

The system gain/loss factors for the various elements of the system are shown in Table III. The tabulated results are shown for man and vehicular targets in the low and high velocity channels of the system.

The calculations show that the system will function properly under the conditions cited. A man target appearing in the high velocity channel may not have sufficient strength to trigger the alarm circuit. It is more likely that the man will be detected in the low velocity channel where there is ample signal to trigger the alarm.

It should be noted that a high noise figure in automatic radars can be looked on as being desirable, since if the system works well in the presence of its own noise, it will be able to tolerate high levels of EMI or jamming.

3.3 SYSTEM CONFIGURATION

3.3.1 ELECTRICAL

Figure 5 shows a block diagram of an early model of the coherent, balanced 1250 MHz ICW radar briefly used before going to a full pulsed Doppler system.

TABLE III

SYSTEM GAIN/LOSS FACTORS

System Gain/Loss Factors	S/N (dB)		
	Low Velocity Channel Man Target	High Velocity Channel	
		Man Target	Vehicle Target
Single Pulse Gain (Free Space)	-12.1	-12.1	-12.1
Coherent Processor Gain	45.6	38.1	38.1
Non-Coherent Integration Improvement	18.0	18.0	18.0
Balanced Processor Loss	-3.0	-3.0	-3.0
Mismatch Processor Loss	-3.0	-3.0	-3.0
Mismatch Receiver Loss	-3.0	-3.0	-3.0
Foliage Attenuation	-20.0	-20.0	-20.0
Ground Lobing	-1.2	-1.2	-1.2
Target Cross-Section	-3.0	-3.0	10.0
Totals	21.3	13.8	26.8

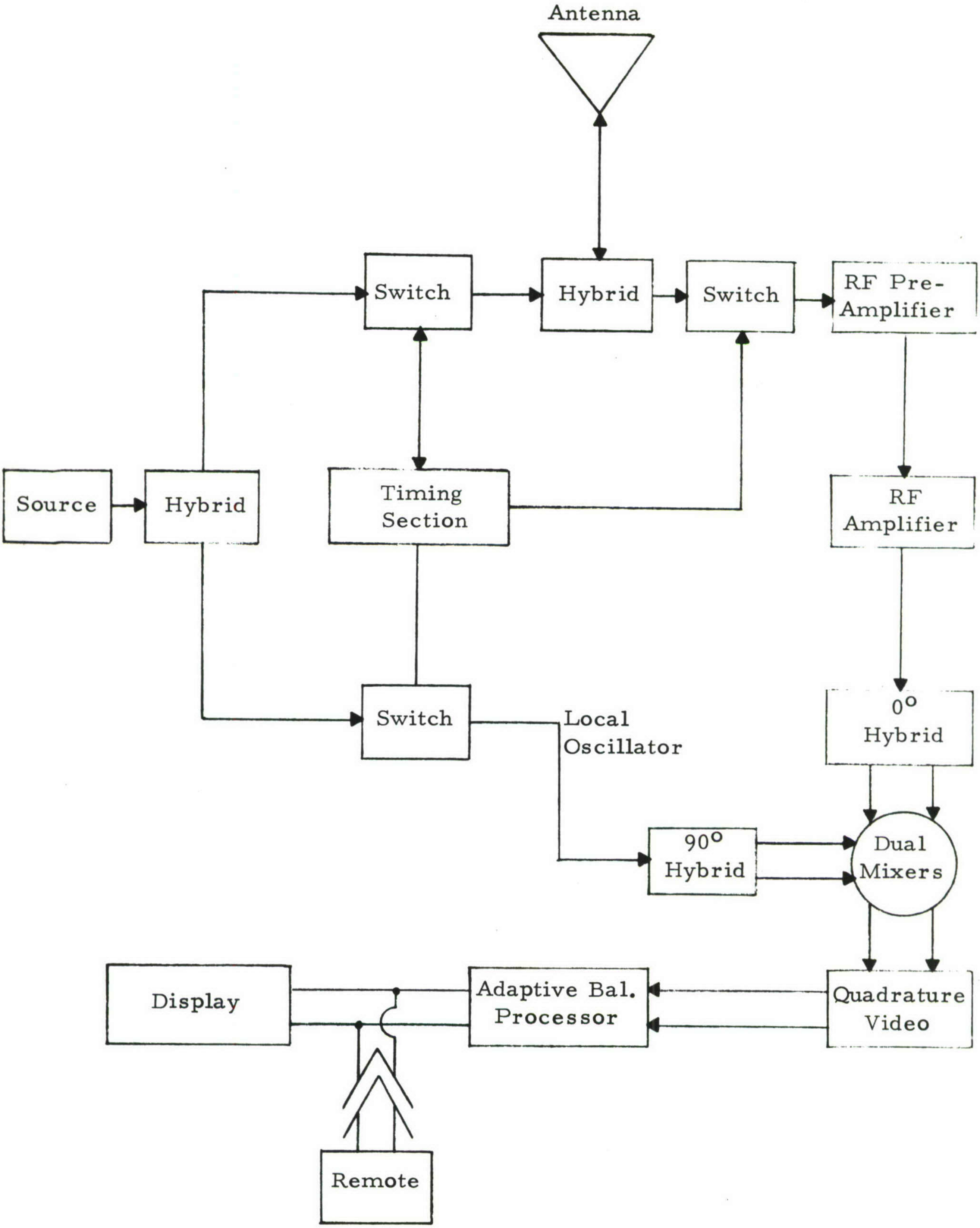


Figure 5: Functional Block Diagram

The crystal oscillator and multiplier provides a common source of 1250 MHz for both the transmitting and receiving portions of the radar. The first hybrid splits the available energy equally between the transmitter and receiver.

The multivibrator provides the basic timing and controls the transmit/receive sequencing, via the RF gate and FET switches.

A single antenna is used for receive and transmit. Transmitter feedthrough into the receiver is reduced to a level which can be tolerated by the receiver by the use of a hybrid. A solid-state switch in place of the hybrid can also be incorporated, but it would add approximately 5 dB loss to the system.

The preselector filter is used to reduce the probability of receiver saturation caused by strong nearby RF fields. The RF amplifier provides a gain of approximately 20 dB to compensate for mixer loss and to insure that the required noise figure is attained in the presence of a high audio amplifier noise figure.

The next portion of the receiver contains the required circuitry to do the conversion of RF to quadrature video for presentation to the inputs of the AB-1100 series adaptive balanced processor. The local oscillator (LO) signal is derived from the 1250 MHz exciter hybrid. Two doubly-balanced mixers whose LO ports are driven from a 90 degree hybrid serve to provide the two quadrature video signals. The FET switches turn off the receiver while the transmitter is on and for a small portion of time thereafter, to reduce the transmitter leakage and to create a dead zone near the radar.

The ARI AB-1100 series processor performs a high-confidence discrimination of the target from the background clutter. A key feature of balanced processing is the ability to differentiate between incoming and outgoing targets. Both the local and remote displays have two visual indicators, one to indicate incoming targets and the other to indicate outgoing targets. The remote display also has a tactile annunciator to arouse the operator's attention without revealing his position.

The control switch simply provides on-off and test selection for the operator. Built-in test equipment is provided to handle the test function.

The ICW concept provides range discrimination. The transmitter is on for 300 nanoseconds, and then off for 600 nanoseconds. The receiver is turned off from the time the transmitter turns on to approximately 60 nanoseconds after the transmitter shuts off. The extra nanosecond off time of the receiver ensures that no return will be received from targets within 10 meters of the LPSD.

A characteristics of the ICW system is that sensitivity increases between the ranges of 10 and 60 meters. At a range of 10 meters the receiver turns on just as the end of the reflected pulse is received, so no energy reaches the signal processors. At 11 meters the received pulse is delayed 6 nanoseconds, and accordingly, the receiver will "see" the target for 6 nanoseconds. As can be seen from Figure 6, the received pulse width increases as the range increases to 60 meters. Between 60 and 100 meters, the primary detection zone, the sensitivity is reduced by normal space attenuation. At a range of approximately 160 meters, receiver sensitivity is abruptly reduced.

3.3.2 MECHANICAL

Figure 7 shows a sketch of an early proposed mechanical configuration of the LPSD.

The bottom part of the case was to contain a plastic tube which was to hold two BA-1100/U batteries with an insertion port to allow either battery to be put in without regard to polarity. The remainder of the case, with the exception of provisions for controls and the antenna, was to be modular with printed circuit cards set up in subracks. The RF section was to be completely shielded to prevent RF leakage into the signal processing section.

The antenna was to be automatically deployed by springs when a catch at the bottom of the case was released. Consideration was given to the use of a printed dipole to allow it to be stored compactly between the faces of the corner reflector when it was in its folded position.

The case contained provisions for mounting the radar on the trunk of a tree. It also contained a screw hole at the base to allow the use of a tripod. A remote display, in the form of a wristwatch, was considered. A quick automatic disconnect miniature plug provided the operator a means for disconnecting the unit in the case of an emergency. Other remote displays where an audio alarm can be used can also be provided. Various light-weight tripods, such as music stands and the tripod manufactured for the AN/PPS-9 radar, were investigated.

An artists conception of the field operation of the LPSD is shown in Figure 8. The LPSD radar unit with its antenna in the operate position, and the wrist alarm is shown in the insert.

The following mechanical constraints design objectives were provided by LWL and were considered to be necessary for the LPSD to meet its mission objectives.

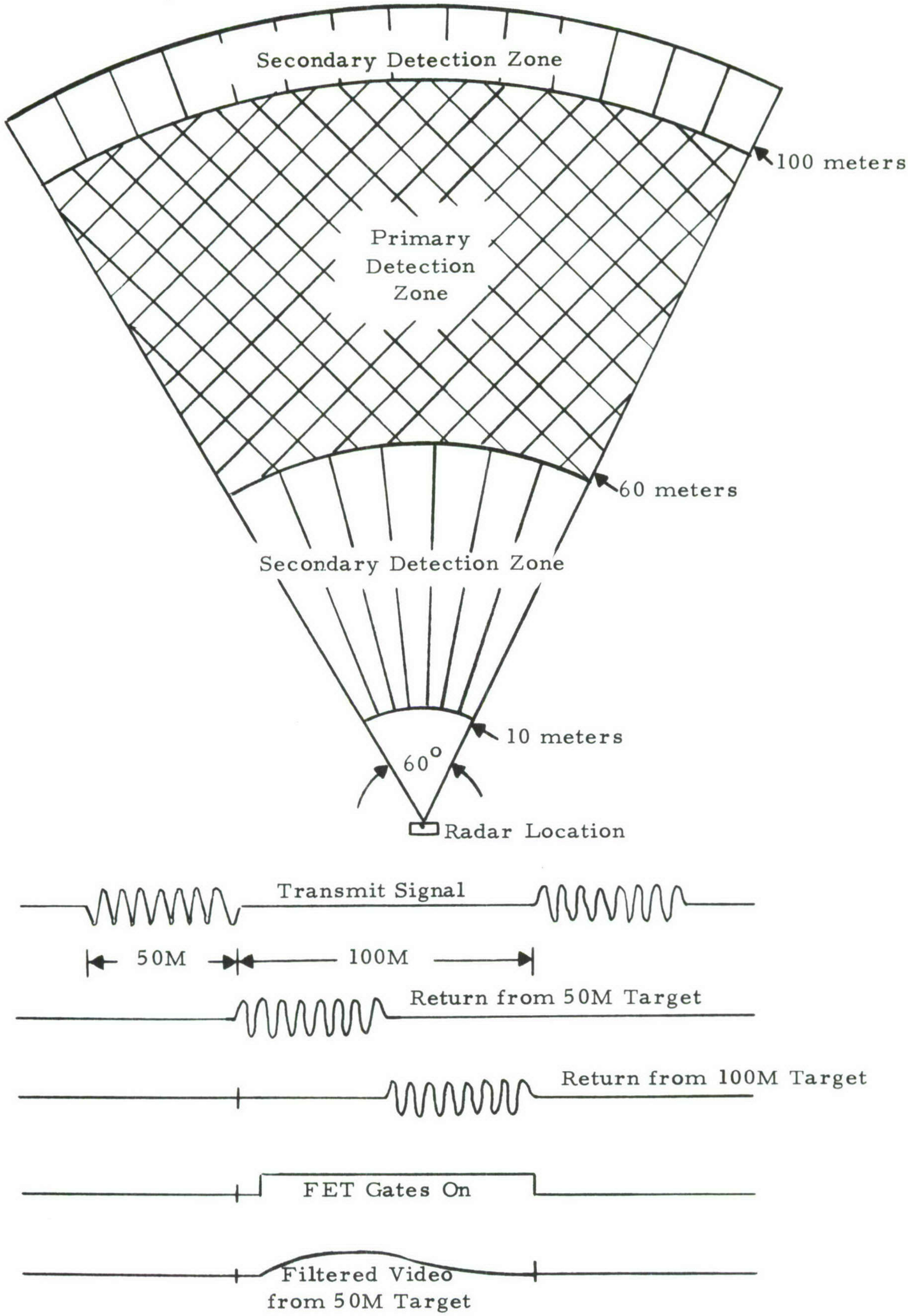


Figure 6: ICW Radar Waveforms

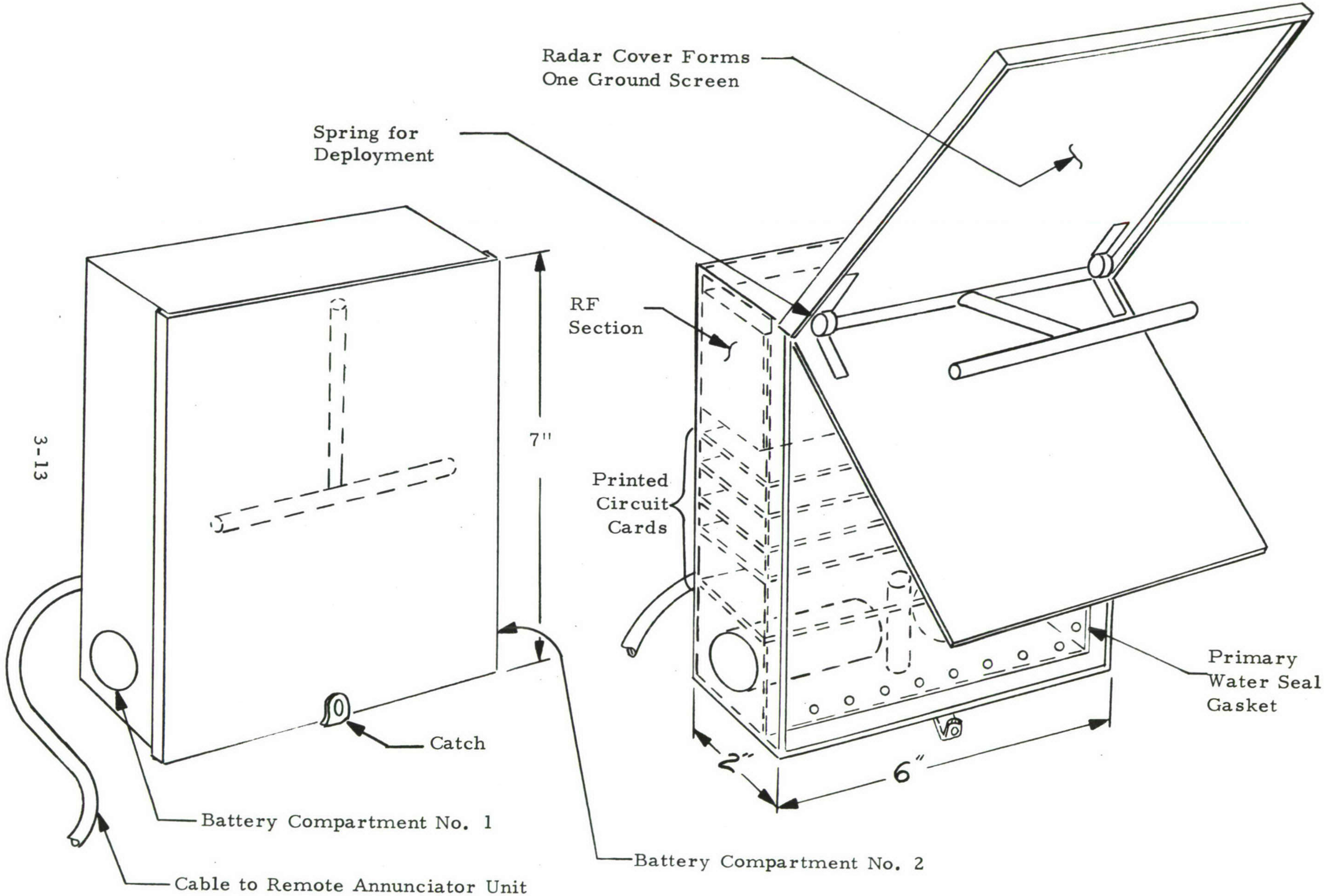


Figure 7: Early Mechanical Configuration of LPSD

Figure 8: Artist's Conception of LPSD in Operational Use

1. The LPSD should have a minimum of projections which will impede movement of the operator in dense vegetation.

2. All LPSD modules (major subassembly or components), should be interchangeable from one LPSD to another with no requirement to trim, calibrate or otherwise match an interchanged module. All LPSD modules should be marked for ease of identification.

3. The LPSD should be water-proof, fungus-proof, and dust-proof in the storage and operational mode. The LPSD should be resistant to salt water, corrosion, fuels, lubricants, fungus, mildews, insects, fire and common cleaning solvents. All LPSD materials should be non-toxic, non-irritating, detectable by x-ray or fluoroscope and contain no element which causes dermatitis or complication to wounds.

4. The LPSD should be compatible with standard U.S. Army combat uniforms and equipment and should allow the operator to adjust and operate the LPSD while wearing standard combat equipment.

5. Operation of LPSD should not create a health or safety hazard to operator or maintenance personnel.

6. A water-proof jack shall be supplied to permit target detection annunciation via an earphone.

7. The LPSD should use military standard parts wherever possible. Connectors and switches should be military standard parts unless clearly demonstrated to the government to be unsuitable for the purpose of the contract objective.

8. The LPSD should require no external cabling.

9. All exterior surfaces of the LPSD, exclusive of connectors and antennas, should be coated by the government with a government developed infrared reflecting olive drab paint.

10. The LPSD should be identified by a suitable identification plate containing the information given below:

LISTENING POST SURVEILLANCE DEVICE
Serial No. ______________________
U.S. Army Limited War Laboratory
(Contractor's Name and Contract No.)

This identification plate should be permanently attached to one area of an exterior surface of the LPSD and should remain legible under all environmental conditions.

11. The LPSD should be provided with water-proof covers for all exposed connectors. These covers shall be suitably attached to the LPSD housing by means of nylon cable.

12. The LPSD design should strive for the following maintenance characteristics:

(a) The LPSD should have a self-test feature to inform the operator of any malfunction, especially deteriorated detection capability.

(b) User maintenance should consist of only normal care and cleaning, and replacement of the power source (BA-1100/U).

(c) A cellular or modular plug-in and plug-out design should be used for ease of maintenance. All major components or modules should be marked for ease of identification. Modules will be keyed to preclude improper plug-in.

(d) The design should permit ease of access to items normally needed to be checked for maintenance.

(e) Test points for all major subassemblies of LPSD should be located for ease of trouble-shooting and maintenance.

(f) All screws, bolts or other parts that require a tool for mounting or dismounting the LPSD or any of its major subassemblies should be captivated and of a type that requires only common tools when worked. No tool should be required to emplace or replace the power source (BA-1100/U).

(g) The LPSD should be capable of being repaired and tested using equipment and tools now found at direct and general support maintenance points within the U.S. Army. If possible, modules should be designed such that module cost is lower than expected cost to repair, allowing throwaway of malfunctioning modules. No special tools, equipment or skills should be required to repair or test an LPSD at direct and general support maintenance points.

13. The LPSD design should include the following human engineering characteristics:

(a) The LPSD should be capable of easy, convenient operation with the location of displays and switch such that the operator is required to perform a minimum of movement.

(b) The LPSD should be designed in conformity with human engineering principles, emphasizing ease of handling, operation and carrying. The LPSD must be compatible with load carrying equipment now used by a typical, combat-equipped U.S. Army rifleman.

(c) The LPSD should include permanently attached instruction for its use.

(d) The LPSD control and functional markings should be shaped and placed so as to be readily identifiable under all conditions of weather and visibility.

(e) The LPSD is intended to be operated by a combat rifleman as an additional duty and should require neither additional personnel or special operator skills.

14. One LPSD will be tested for the following characteristics:

(a) High Temperature - The LPSD should be immersed in air at 125°F and its temperature stabilized. The LPSD should be subjected to solar radiation at a rate of 360 BTU/ft^2 hr for a period of 4 hours. The LPSD should be operated throughout this test. Any undesirable effects or malfunction should be noted and recorded.

(b) Low Temperature - The LPSD should be immersed in air at 20°F, without solar radiation, and its temperature stabilized. The LPSD should be subjected to these conditions for a period of 4 hours. The LPSD should be operated throughout this test. Any undesirable effects or malfunctions should be noted and recorded.

(c) Humidity - The LPSD should be immersed in air at 125°F and relative humidity of 90% to 95% for a period of 24 hours. The temperature of the air should then be reduced and held to room temperature for a period of 24 hours. The temperature of the air should then be increased and held to 125°F for a period of 24 hours. The LPSD should be operated at least once every 24 hours for a 30-minute period to detemine if it is functioning normally. The LPSD should be operated just prior to and just after the humidity test. Any undesirable effects or malfunctions will be noted and recorded.

(d) Barometric Pressure - The LPSD should be immersed in air at 20°F and its temperature stabilized. The LPSD should be subjected to ambient pressure change from a simulated altitude of 0 feet to a simulated altitude of 8,000 feet at a rate of 2,000 feet per minute. The LPSD should be held at 20°F and 8,000 feet for 12 hours. The simulated altitude should then be changed from 8,000 feet to 0 feet at a rate of 2,000 feet per minute and the LPSD will be allowed to return to room temperature. The LPSD should be operated just prior to and just after this Barometric Pressure test.

(e) Drop Test – The LPSD should be allowed to free fall from a height of 3 feet onto a cement surface in the following manner:

Impact Zone	Number of Drops
Each face of all outer surfaces	3 on each face
Each corner of all outer surfaces	3 on each corner

The LPSD should be operated just prior to and just after this test. This test should be performed prior to the vibration test. Any undesirable effects or malfunctions will be noted and recorded.

(f) Vibration – The LPSD should be vibrated from 5 to 32 cycles/sec at 1.5 g input for 15 minutes at a sweep rate of 3.1 minutes maximum to minimum frequency. The LPSD should be vibrated from 32 to 52 cycles/sec at 2.5 g input and from 52 to 500 cycles/sec at 4 g input for 3 hours at a sweep rate of 4.3 minutes, minimum to maximum frequency. This test should be conducted for each of three primary, mutually perpendicular axes of the LPSD. The LPSD should be operated just prior to and just after this test. Any undesirable effects or malfunctions should be noted and recorded. The LPSD natural frequency (and amplitude) of vibration should be determined and recorded.

(g) Water Immersion – The LPSD should be immersed to a depth of 3 feet in fresh water at a temperature of 40°F for a period of 3 hours, removed and immediately immersed to a depth of 3 feet in fresh water at a temperature of 80°F for a period of 3 hours. Leakages, loss of sealing or other undesirable effects should be noted and recorded. This test should be conducted as soon after the drop and vibration tests as practicable.

(h) Field Tests – The LPSD should be operated in as dense foliage as is readily available to the Contractor a sufficient number of times to provide a statistical base to demonstrate that LPSD meets the required detection characteristics.

(i) Assemble the spare parts from the list of recommended spare parts included in the Phase I report, as approved by the Technical Supervisor. These parts and assemblies should be identified in a manner which allows their rapid selection when required for use.

4.0 BREADBOARD MODEL

The first LPSD breadboard was demonstrated on 1 April 1969. The demonstration proved beyond any reasonable doubt that close-in objects, like the operator, can cause difficulties with a CW radar.

The demonstration breadboard was less sensitive than required to detect moving personnel at 100 yards through foliage. The reasons for the low sensitivity were:

a. Antenna hybrid too lossy by approximately 10 dB

b. LO power in the vicinity of 2 to 4 mW

c. 0 degree hybrids lossy

d. VSWR generally too high throughout the system

e. Transmitter power 8 dB low

f. Antenna gain 5 dB low

Despite these great losses, the breadboard did demonstrate some of the features and problems associated with a CW system. The ICW system greatly reduces these problems.

The first antenna chosen was a corner reflector antenna. It was selected because of the following reasons.

a. Gain is relatively high

b. The beam in the vertical plane is narrow

c. The beam is relatively broad in the horizontal plane

d. Good front-to-back ratio

e. Mechanically collapses easily into a small package

The ICW approach also required changes in the antenna hybrid. The source in an ICW system can be turned on and off with a 300 nanosecond pulse. The only other change to the breadboard required some FET's to gate the mixers into the audio amplifiers.

4.1 ICW DESIGN

The ICW technique increases substantially the complexity of the system as well as the power consumption. RF switching transition

times were so long that there was considerable sensitivity to nearby return, and yet the receiver did not achieve maximum sensitivity until near maximum range. One of the tasks was to improve on RF switch performance.

Mixer unbalance resulted in some RF being radiated by the antenna during the receive mode, resulting in some nearby clutter return. The use of a RF amplifier in the receive mode improves this isolation and tends to improve the system noise figure.

The sub-audio amplifiers used in the first prototype were microphonic and expensive. The use of RF pre-amplification allows the use of other amplifier types which are less expensive and not microphonic.

Adding a RF amplifier increases the size, weight, and power consumption, but the resulting improvement in system performance is worth consideration.

4.1.1 POWER CONSUMPTION

Expected battery life was a matter of great concern. The plan was to operate the unit on two BA 1100/U batteries. The current drain on these batteries was estimated to be 200 milliamperes. At this load the operating life of 10 hours can be expected. Additional effort was made to reduce this power drain.

Two mercury batteries operated in series to provide an unregulated +12 volt supply was considered as the power source for the RF oscillator and RF amplifier. A regulating converter was to be used to provide $\pm$ 6 volts. This arrangement automatically equalizes the load on the two batteries which is highly desirable. The RF oscillator and the RF amplifier consume about one-half the power, so the use of unregulated power for these modules is desirable from an efficiency point of view.

The timing and switching circuits underwent re-evaluation and re-design to improve the performance and reduce power consumption.

The RF source drew 75 milliamperes, making it one of the major power drains. The DC to RF efficiency was approximately 9%. The unit was already fairly well refined, so further improvement in efficiency was not expected to come very rapidly; additional development was deferred on this aspect of the design. Possible approaches considered in an attempt to reduce power consumption were (a) reduce the current and/or voltage to the oscillator, buffer, and multiplier stages, (b) to consider alternate multiplication schemes and ratios, and (c) to further refine the high level stages of amplification. It was expected that input power might be cut by one-third.

The RF amplifier was considered to be reasonably satisfactory at the breadboard stage. The current consumption of 25.5 milliamperes could probably be reduced by several milliamperes with little or no effect on performance. The reverse isolation, which was expected to be an important characteristic of the system, was to be further refined also.

The power supply converter circuits, of necessity, were of the switching type. This created EMI problems. Fortunately the most sensitive parts in the unit, the Doppler amplifiers, are only required to pass a signal in the 1 to 20 Hz frequency range. Substantial filtering was incorporated to discriminate against converter EMI.

5.0 PRELIMINARY TESTING OF THE SYSTEM

A comprehensive series of in-house tests were conducted to insure compliance with the system performance requirements described in the LPSD contract. The tests were divided into three types:

1. Detection performance
2. Environmental
3. Human engineering

5.1 DETECTION PERFORMANCE TESTS

For these tests, a walking and a crawling man were introduced at various ranges and under various conditions of foliage, wind, and at various velocities. Complete statistical records of detection performance and false alarms were kept to determine conformance with performance requirements, and also to see under what conditions reliable performance could be obtained at even longer ranges.

5.2 ENVIRONMENTAL TESTS

It is expected that radars of this type would be subjected to severe punishment during normal field use, therefore, it was felt that environmental tests were perhaps equally as important as performance tests. The planned fabrication of two initial units, one for performance evaluation and one for environmental testing, allowed both tests to be carried on simultaneously. The tests to be conducted were in accordance with the requirements stated in the contract.

5.3 HUMAN ENGINEERING TESTS

A great deal of thought was directed in the initial design of the system toward allowing the system to be set up readily and used by a relatively untrained operator. A series of experiments were conducted where operators who never used or even seen the equipment were given brief periods of instruction ot not more than 30 minutes. They were asked to set up the system, put it into operation, and demonstrate reliable detection performance.

5.4 INITIAL FIELD TESTS

A series of field tests were conducted in the Boston area to check system performance against known targets.

The first test was conducted in the MDC Parking Lot adjacent to the Charles River as shown in Figure 9. The radar was set in

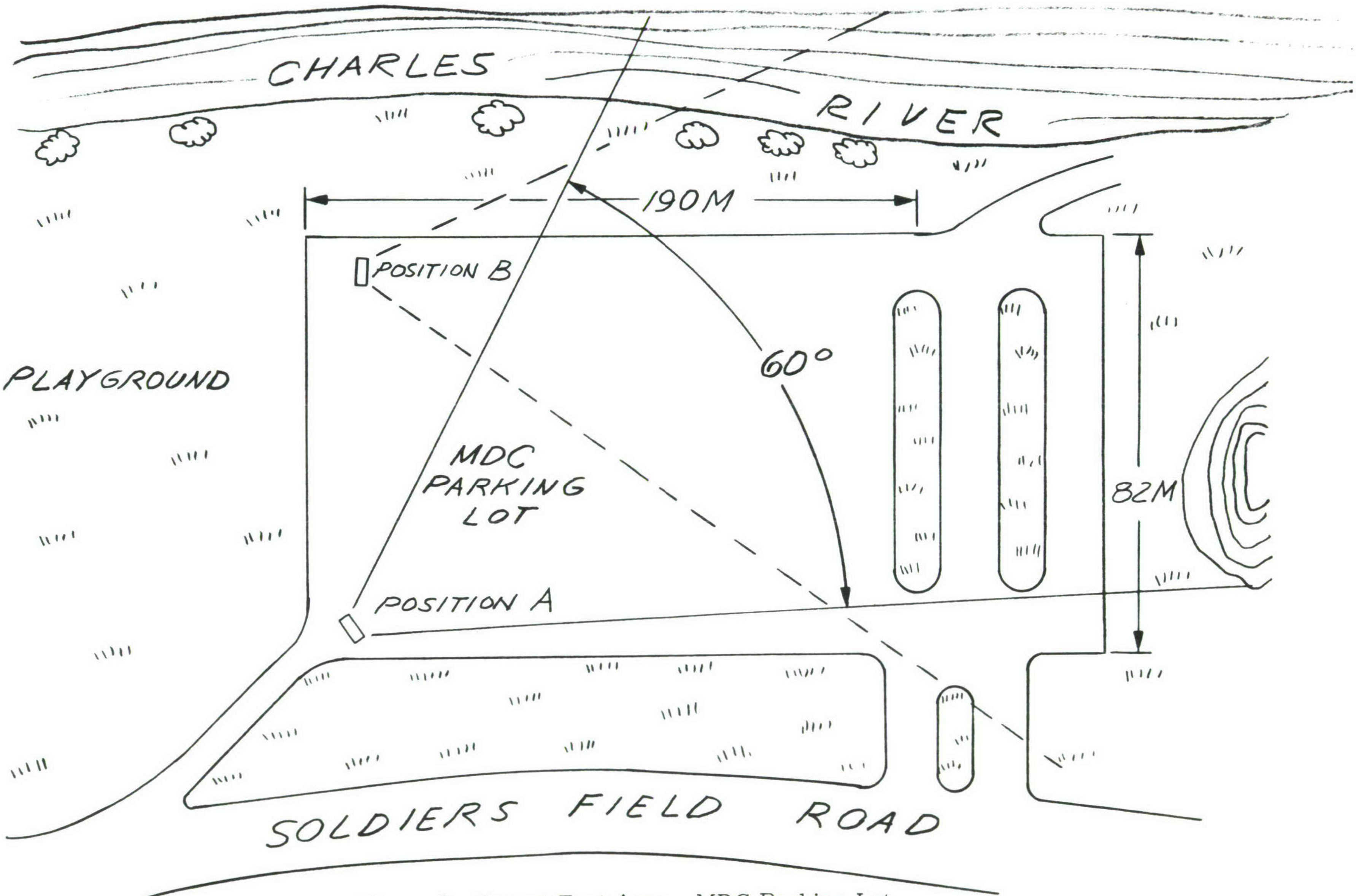


Figure 9: Target Test Area - MDC Parking Lot

position A, and the target was a single upright man walking at a rate of approximately 1.2 meters per second. The detection cell contained no foliage, and the wind was blowing steadily at less than 10 knots.

The target started at the radar location A, and walked along the antenna boresight for approximately 10 meters in 8 seconds, and then paused for 15 seconds, repeating this routine until reaching a range of 130 meters. The routine was repeated in the reverse direction starting at 130 meters until the radar was reached.

During the course of the 24 opportunities that the radar had to detect a target, the radar indicated an alarm and showed proper target direction 22 times. Most of these 22 detections showed large margins (at least 10 dB). The two missed detections appeared to have been caused by an excessive buildup of AGC because a car moved through the detection zone shortly before this portion of the data was taken. The missed detections were at 30 to 50 meters, outgoing. Farther out detections were not attempted although the margin at 130 meters appeared to be good.

A second test was conducted along the Charles River as shown in Figure 10. The radar unit was located in position A, and the wind was blowing steady at 10-15 knots.

The target was a single upright man walking at a rate of approximately one meter per second. The detection cell was 50% filled with leafless trees. The trees were primarily birches 5-7 meters high with an average trunk spacing of 1 to 1.5 meters. Visual occulation occurred in a foliage path of the order of 20 meters deep.

The target started at a point along the antenna boresight path 70 meters from the radar and walked 10 meters, paused 30 seconds, and continued until the 90 meter point was reached. The cycle was repeated on the ingoing direction. Fifteen full cycles of this (70-90-70 meters) were performed.

The radar detected the target for all 60 opportunities. Maximum penetration distance was 45 meters. There were no false alarms before, during, and after the test. Two unexpected targets of opportunity were also detected.

The radar was then set up in position B as shown in Figure 10. Wind was blowing at 45 knots, with gusts up to 60 knots.

The target was a single upright man walking at a rate of approximately 1 meter per second. The detection cell was 50% filled with leafless trees. The trees were birches approximately 5-7 meters high, and an average trunk-to-trunk spacing of 1.5 meters. Visual occulation was approximately 20 meters in this wooded area.

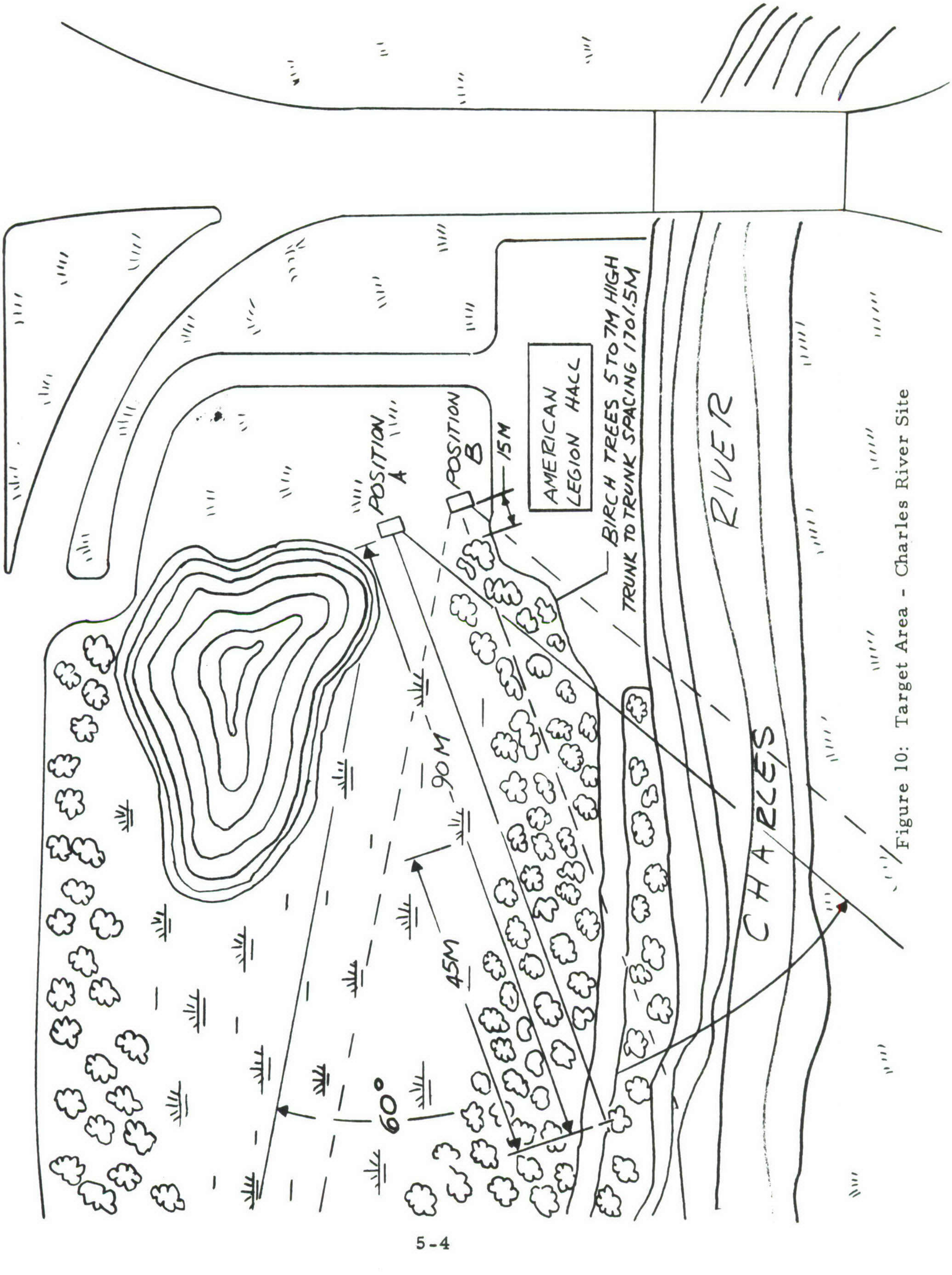


Figure 10: Target Area - Charles River Site

The maximum target range attempted for this test was 60 meters. The target started at the radar and moved 10 meters between each 20 second pause to the maximum range. The routine was repeated in the reverse direction. Two complete cycles (0-60-0 meters) were performed.

Of the 24 opportunities for detection, the radar alarmed on only 8 of these. During the course of one hour of testing there were 2 definite false alarms and 2 other possibles, but were suspected to be targets of opportunity.

Tests were also conducted in a sand flat at Sheridan and N. Park Road, Hollywood, Florida. A map of the area is shown in Figure 11. The wind blew steadily at less than 5 knots.

The target was a 90 lb. 4' 11" boy walking at a rate of approximately one meter per second. A relay-activated flashlight connected to the remote annunciator terminals was used for radar alarming. The meter box was connected to allow viewing of integrator outputs. The center of the radar antenna was 1.5 meters above ground.

The target started at approximately 150 meters and walked toward the radar until an alarm sounded. An X was marked in the sand where the integrator started to decay. This was repeated at 14 different azimuth locations from boresight to approximately 85 degrees on either side of boresight. Distances to the X marks were measured and recorded.

Figure 12 shows the maximum ranges at which the target was detected as a function of angle, both for incoming and outgoing targets.

A spot check was made on a 200 lb 6' 1" man on boresight. Indication occurred at 140 meters incoming and 155 meters outgoing.

There was one spurious alarm during the 3 hours of testing. It was caused by backlobe return from a flatbed tractor-trailor carrying a bulldozer moving along the road at a slow speed at approximately 80 meters.

The sand flat shown in Figure 11 was also used to detect a 200 lb, 6' 1" crawling man at the rate of approximately 2/3 meter per second. A relay-activated flashlight connected to a remote annunciator was used to indicate radar alarm. The height of the radar was placed first at one meter, then at 1.5 meters.

The target started at a range of 100 meters, and crawled (hands and knees) towards the radar. The tripod height was increased and the test was repeated. Similar detection of a low crawl, military style, was tried starting at a range of 80 meters.

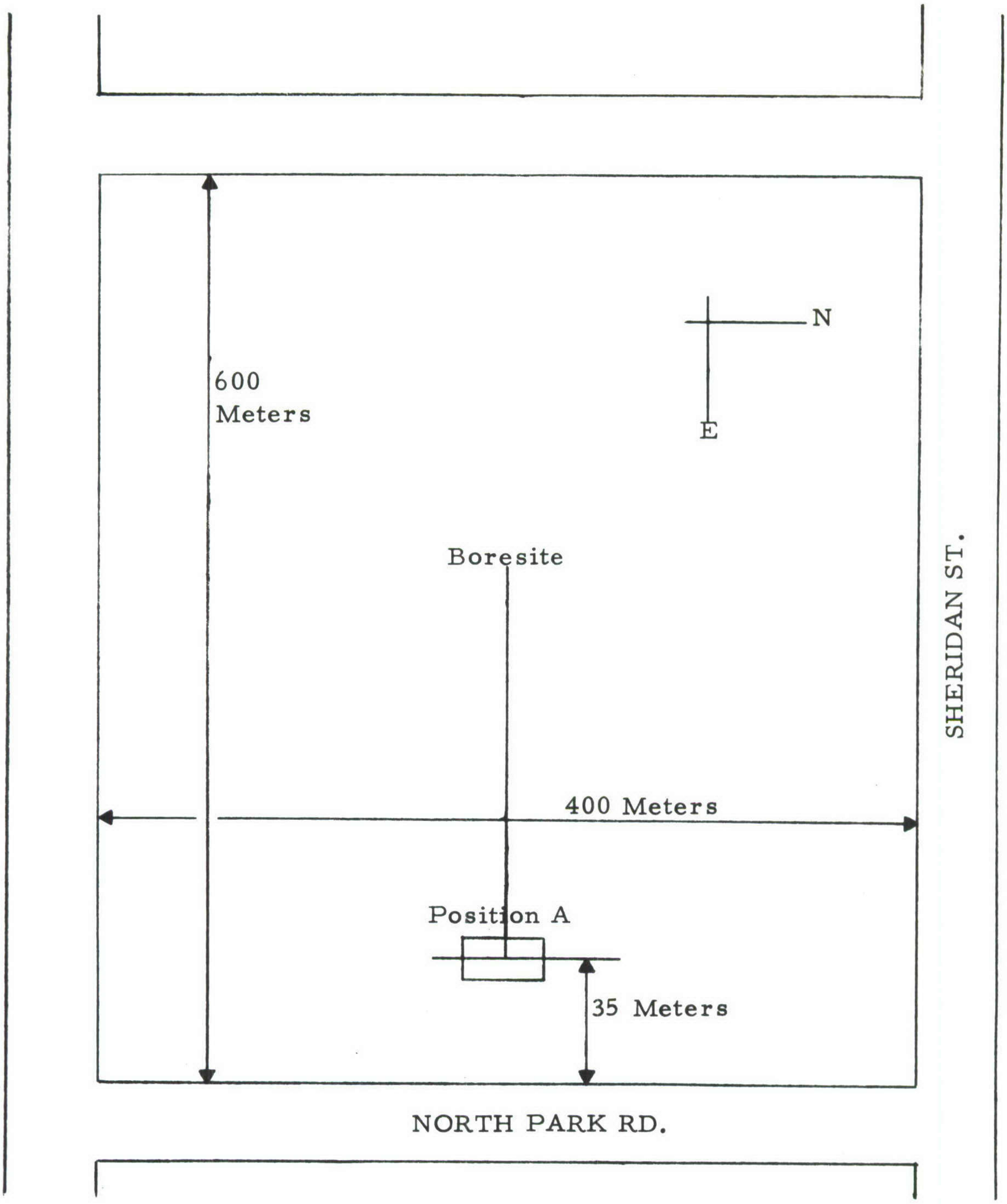


Figure 11: Hollywood, Fla. Test Site

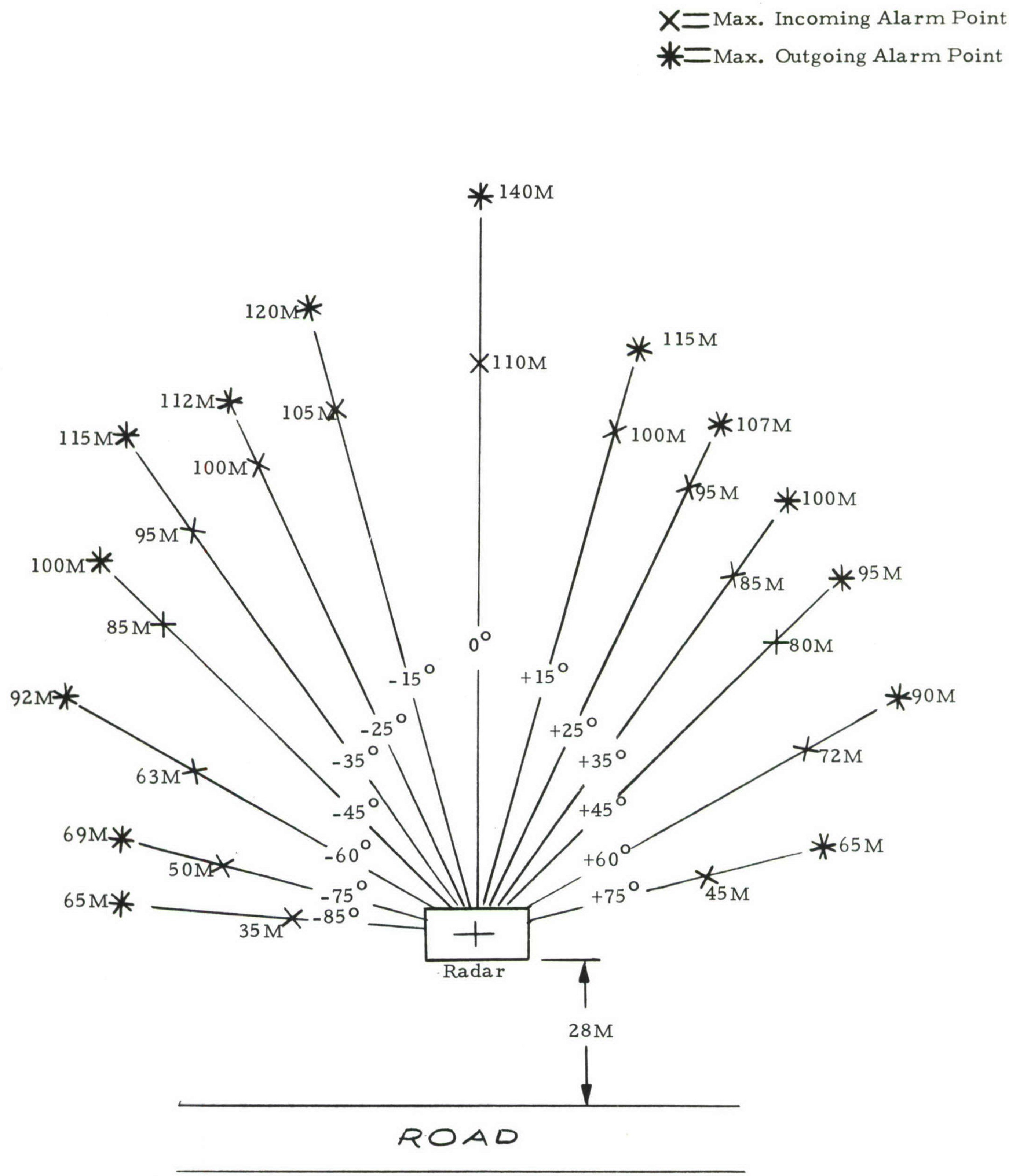


Figure 12: Detection Range vs. Angle of Detection

The crawling target was detected at 70 meters with the radar height set at 1 meter. This range increased to 80 meters when the radar height was increased to 1.5 meters. With this radar height, the low crawl was detected at 68 meters.

A wooded area was next selected in the Sheridan Street Area as the target area. This site is shown in Figure 13. The radar was positioned at A and the wind was blowing steadily at 5 knots.

The target was an upright, and for a brief period, a crawling man at a range of 50-90 meters. A meter box which showed high and low balanced integrators, AGC voltage and AFC voltage, at the end of a 100 meter length of multi-conductor cable was used to observe the radar outputs from the target detection zone. A "missed target" is defined as one requiring at least 15 steps to detect.

The target started inbound through foliage at 85 meters, and walked until the integrator charged to alarm level. The number of steps required to trigger the alarm was recorded. This was repeated for outbound and inbound targets. This sequence was repeated at 75 and 65 meters, and at -30°, -20°, -10°, 0°, 20°, and + 30° from boresight.

The results of these tests are tabulated in Table IV.

The results are surprisingly similar at the three ranges. Hands and knees crawl was fairly reliable at 50 meters, both inbound and outbound, but it was marginal at 65 meters. Inbound traffic was undetectable generally at 65 meters.

5.5 EFFECT OF ANTENNA HEIGHT ON PERFORMANCE

During July 1970, two LPSD's were tested for operation against a crawling man. The main purpose of the tests were to determine if raising the LPSD antenna height would improve the performance against a full military crawl.

As shown in Figure 14, the test area consisted of a forked road surrounded by large amounts of foliage. The foliage consisted of birch, pine, and oak trees between 10 to 30 feet high. Throughout these tests, the wind velocity was between 15 and 30 knots. As a result there was a considerable amount of clutter resulting in relatively high values for the AFC and AGC. The adaption values were:

Function	Meter Reading	Approximate Value
AFC	15	Cutoff of 3.5 Hz
AGC	10-15	Gain reduction of 6 dB

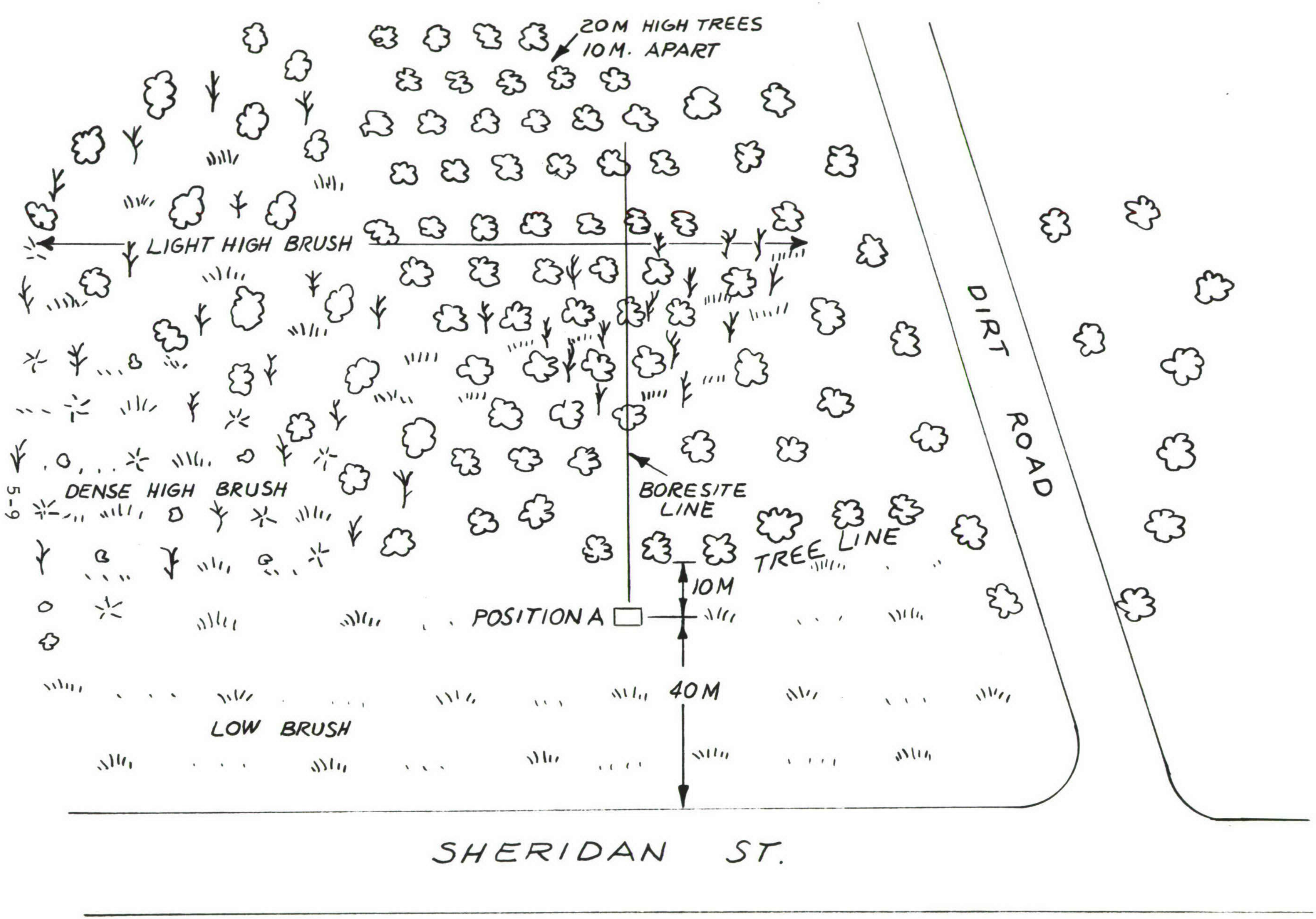


Figure 13: Wooded Target Area - Sheridan Street Area

TABLE IV

NUMBER OF STEPS FOR DETECTION vs. RANGE AND ANGLE IN FOLIATED AREA

Range (Meters)	Angle Relative to Boresite (degrees)	Number of Steps Incoming	Outgoing
65	-30	9	5
	-20	4	3
	-10	5	4
	0	2	1.5
	+10	6	4
	+20	4	2
	+30	3	3
75	-30	4	2
	-20	5	3
	-10	Miss	Miss
	0	4	3
	+10	4	2
	+20	3	1.5
	+30	6	4
85	-30	7	3
	-20	6	3
	-10	7	3
	0	13	Miss
	+10	2.5	2
	+20	10	3
	+30	3	2

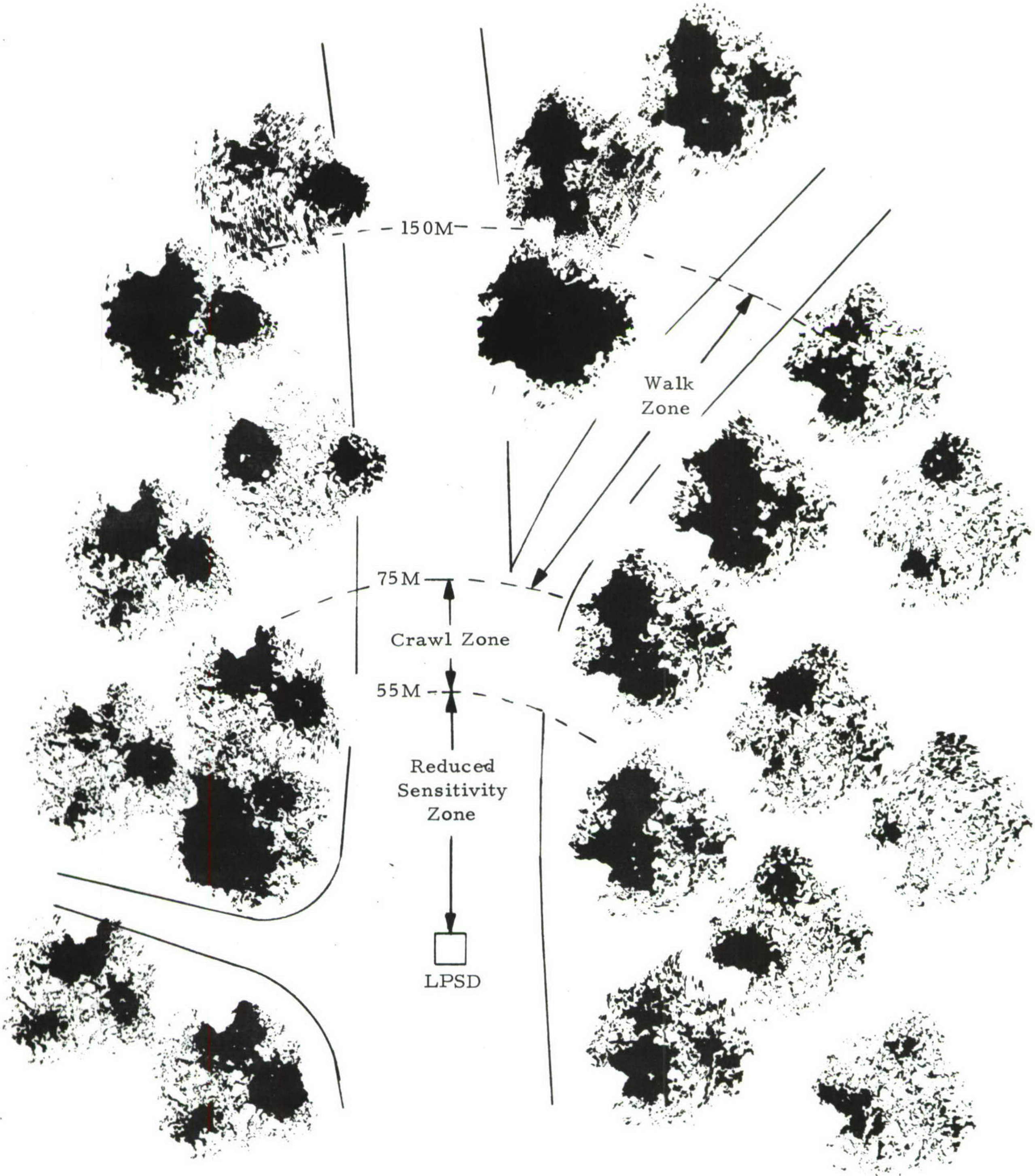


Figure 14: Test Site - Westford, Mass.

The test was conducted with the radar dipole at two heights, five feet and ten feet. The man performing the full military crawl was not detected at either height. There was a definite movement in the integrator output, however, when the antenna height was raised. At five feet, the integrator consistently read one-half small division on the low velocity scale. By raising the antenna to ten feet, the integrator consistently read three times higher or 1-1/2 divisions. This corresponds to 1/4 and 3/4 respectively of the detection threshold.

As a further test of the improvements due to antenna height, range for a walking man was measured. The results are tabulated below.

Antenna Height (Feet)	Range for Walking Man (Meters)
5	115
10	150

The improvement was quite noticeable. At 115 meters, the difference in antenna heights caused the radar to alarm at two steps rather than the six steps typically required previously. Throughout the tests, the radar was mounted in a rather sheltered area, such that the high winds did not cause any noticeable shaking of the radar and/or its mount.

The high wind velocity on the day of the tests provided one of the rare opportunities to observe the operation of the LPSD in this type of an environment. The range cell was completely full of blowing foliage. The results for two systems tested (EA-2 and EA-4) are tabulated as follows:

System	AFC	AGC	Range*	False Alarms
EA2	15	10-15	115	0
EA4	15	15-20	115	1

Some other observations made during the tests were as follows:

1. Several false alarms occurred during the first few minutes of operation until the equipment adapted to the background.

2. It is anticipated that system EA2 would have detected the crawling man with the antenna 10 feet high, if (a) the reduced sensitivity zone was less than 50 meters, and

* The antenna ground height was 5 feet at all times measured to the center of the dipole.

(b) the wind had not caused the low frequency cutoff to be as high as 3.5 Hz.

3. System EA2 had approximately ± 1 division peak (half the threshold) swing in its integrator. It never false alarmed. No offset was noted.

4. System EA4 had typical swings of approximately ± 1 division. Peak deviations were ± 1-1/2 divisions. It had one false alarm (in the high velocity channel).

5. The swing in the high channel was the result mainly from too short a time constant in the high frequency time on target indicator. This should be increased in later production units.

6. The low frequency channel had almost no deviations or offsets. They were less than ± 1/3 division. Actually the low channel seemed almost too quiet.

7. The ability of the LPSD to detect targets in the presence of large amounts of clutter is quite good. No evidence of small signal suppression in the high channels was noted.

8. Raising the antenna height to 10 feet definitely improves signal to clutter ratio for targets at maximum range in the clear.

5.6 DETECTION OF WATER-BORNE TARGETS

A brief series of over-water tests was conducted in July 1969 to determine how well slowly-moving water-borne craft could be detected.

The system used of the tests was a small, battery powered, interrupted (ICW), L-band, automatic-alarm radar. The breadboard system transmitted approximately 25 milliwatts of average power in a $60^{\circ} \times 60^{\circ}$ beam. Automatic alarm operation was obtained using a balanced adaptive signal processor.

The RF transmit duty cycle was 30%, with the ON time providing a 50 meter resolution cell size. The transmitter and receiver timing was set up in such a way as to create a relatively "dead" zone for the first 20 meters of range followed by a 80 meter zone of full sensitivity. At 100 meters, the sensitivity tapered off sharply, going to zero at 150 meters. These values can be changed by revising pulse widths in the radar timing sub-section.

5.6.1 GEOMETRY AND LOCATION

Figure 15 shows the geometry that was used for the experiments. The radar was placed at a point approximately 8 meters from the water, measured along the beam boresight, and the beam was pointed partly upriver to be certain that all targets had a significant radial velocity component. The radar antenna height was approximately 2 meters above the river water level, and was located approximately 3 meters from the nearest foliage. The river was approximately 50 meters wide, and the foliage was fairly dense along both banks. The foliage along the left bank consisted of trees and bushes to a height of about 15 meters. The foliage along the right bank was about 1.5 meters high and consisted of heavy brush. Figure 16 is a photograph of the test area taken from the railroad bridge. The radar location cannot be seen in the photograph, but it was located at a point below the lower left hand corner by about 30 meters.

The test area was located on the Sudbury River just before it passes under Route 62 in Concord, Mass., and just before it joins the Concord River. This particular site was chosen because of the dense foliage that it had along one bank, and because of the availability of a large number of targets of opportunity due to the proximity of a boathouse in the area. Figure 17 shows the radar viewing one of the many targets of opportunity.

5.6.2 CONDUCT OF TESTS

In addition to running detection experiments on targets of opportunity, a series of controlled experiments were conducted using a canoe. For the controlled experiments, the 60° azimuthal coverage of the radar was divided into 5 angular zones shown as Zones 1 through 5 in Figure 15. The canoe was then paddled back and forth slowly through the far end of each ofthe five zones three times (15 incoming and 15 outgoing passes).

5.6.3 RESULTS

Figure 18 shows a plot of the average margin of the signal processor's integrator output above the automatic-alarm threshold when the radar was viewing a controlled target.

The automatic-alarm detected every target of opportunity and every controlled target, however, it was clear that detection in Zone 5 showed very little margin above the alarm threshold. This was probably due to the fact that the radar beam had to penetrate the local foliage in front of the radar plus some additional foliage farther up-river.

The wind was fairly low, going to a maximum of about 7 knots. The radar never false alarmed during the experiments, however, it did alarm several times when people walked towards the system.

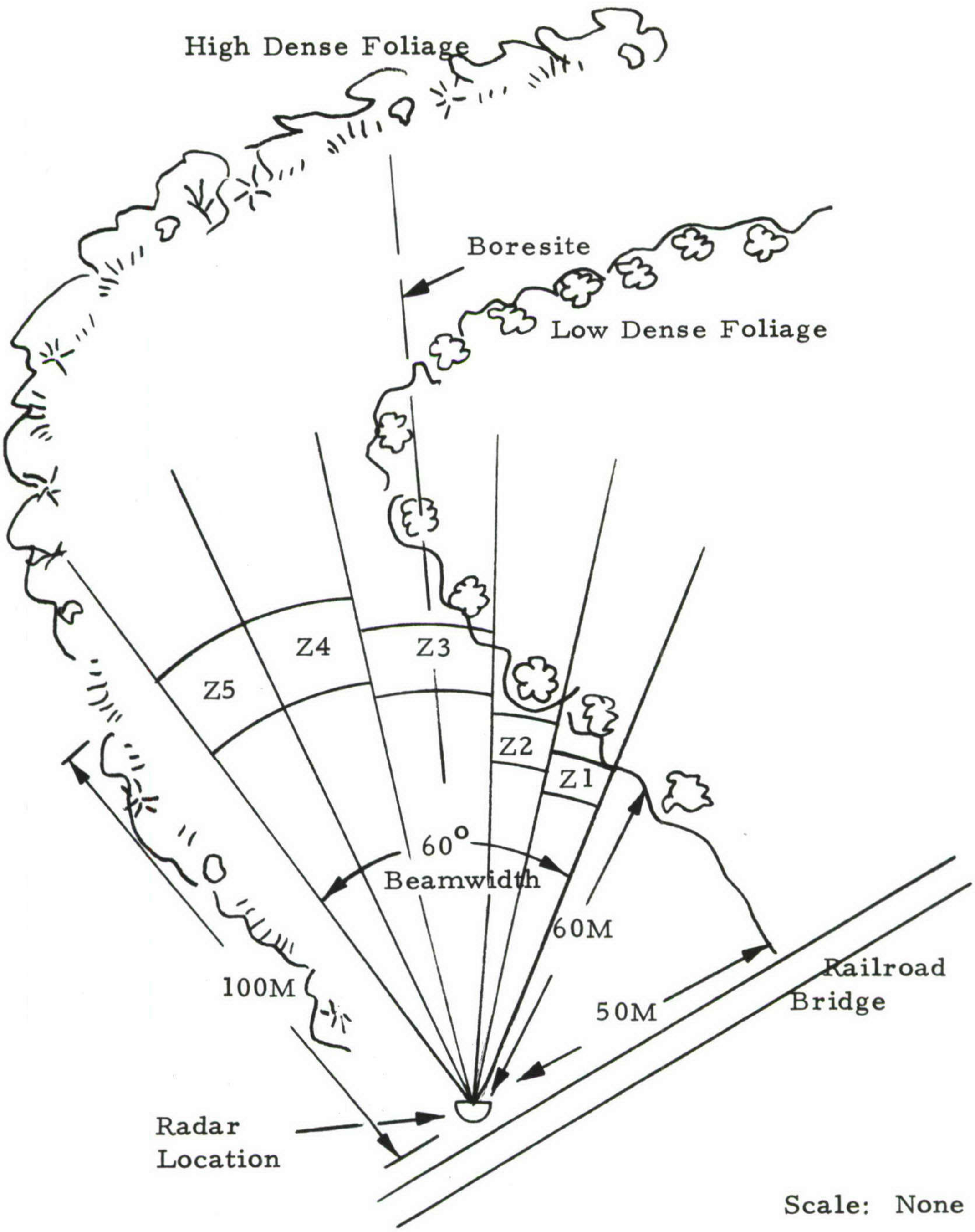


Figure 15: Geometry of Test Area

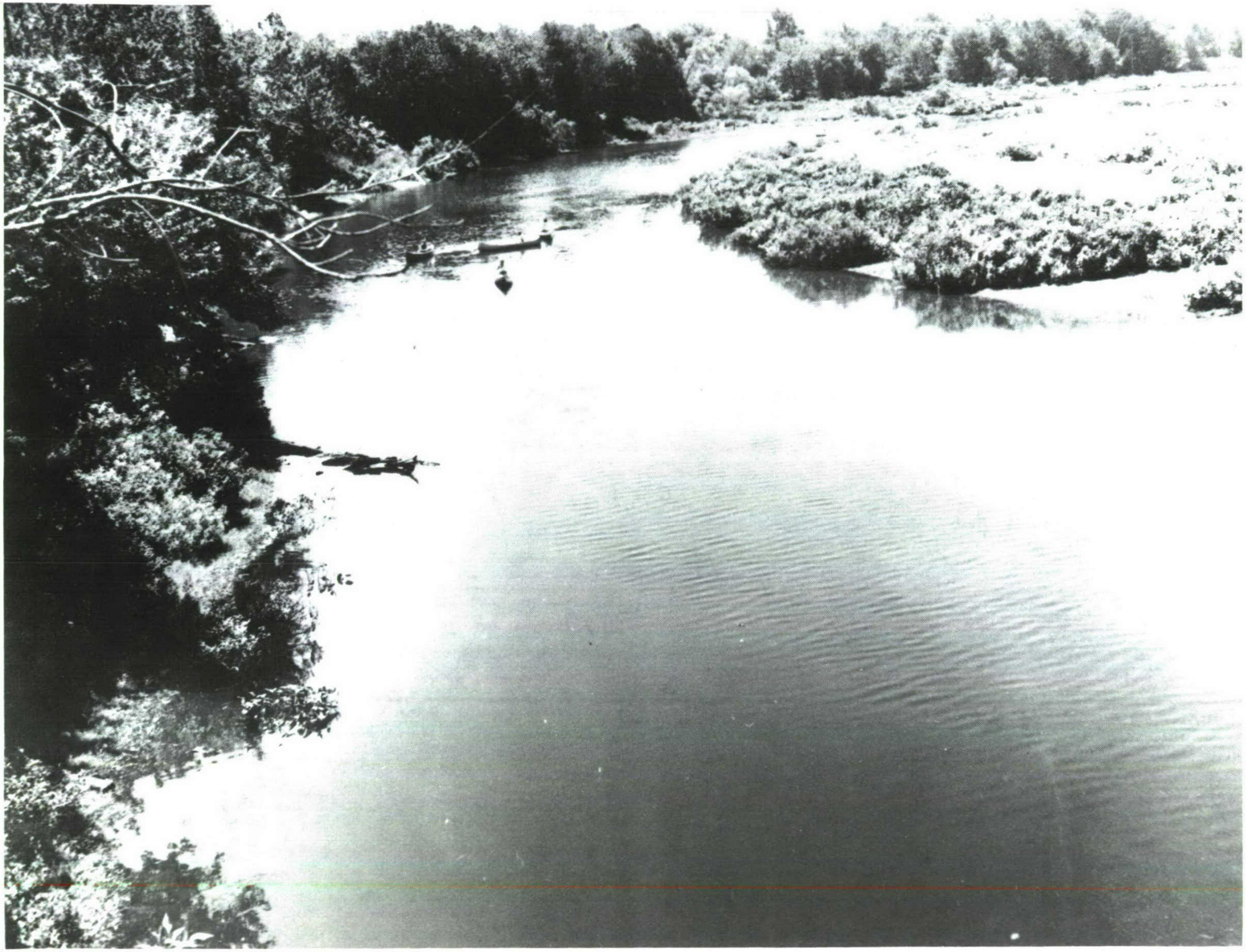


Figure 16: Photograph of Test Area from Railroad Bridge

Figure 17: Photograph of Test Area Showing Radar Location

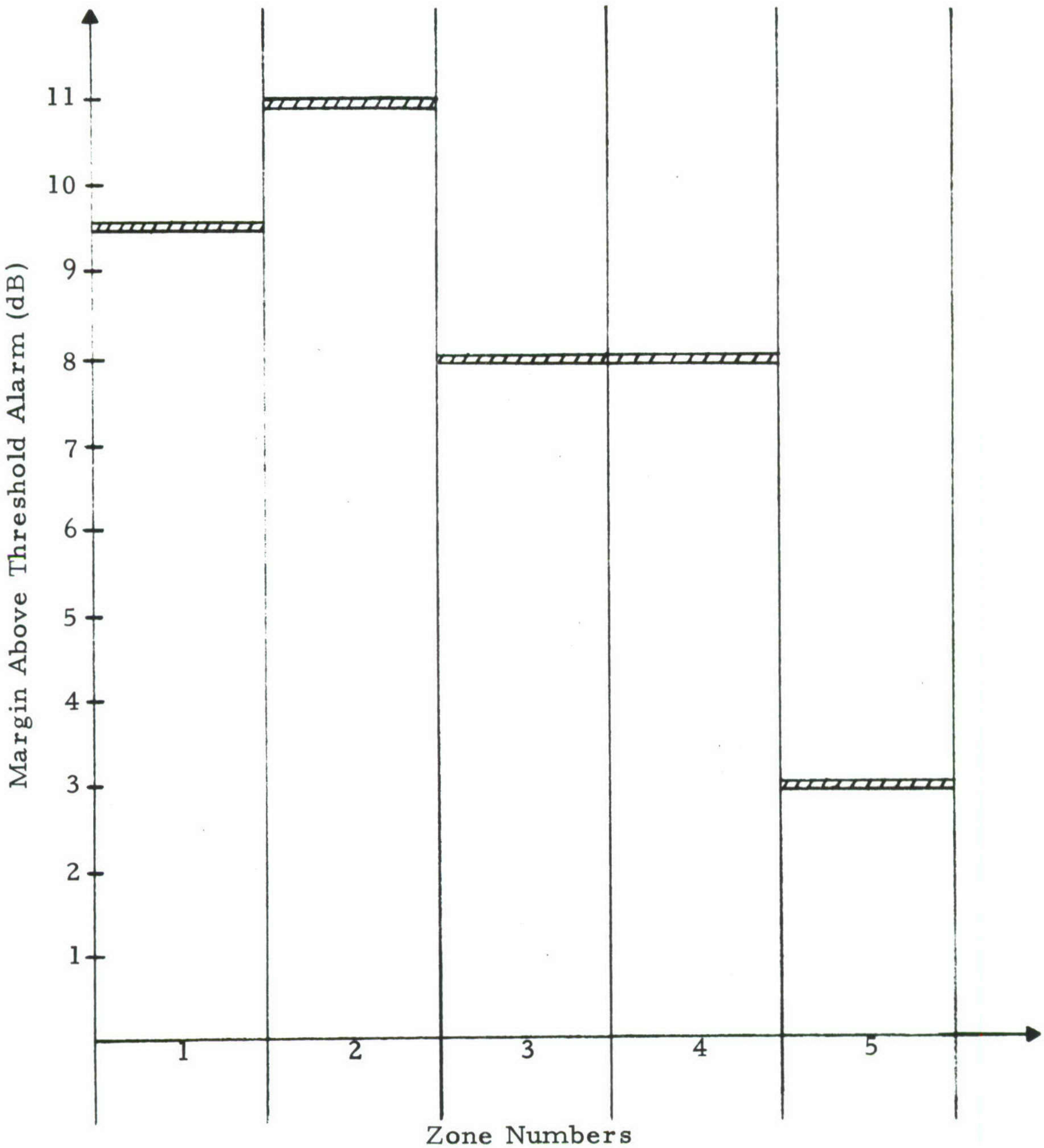


Figure 18: Average Detection Margin for Each Zone

The reliability of detection, both for targets of opportunity and controlled targets, was good. The system operated well without requiring any special set up procedures or adjustments. This probably can be attributed to the proper selection of frequency and amplitude adaptive feature of the signal processor. The system automatically adapted to the foliage clutter it viewed in the experimental area.

5.7 EXTENSION OF TARGET DETECTION RANGE

Tests were conducted during the first week of August to determine if the target detection range of the present LPSD could be extended to 200 meters.

Testing was done on LPSD, Serial Number "Zero". Except where noted, all tests were conducted with a man walking along the boresight of the radar in an open field. Unless otherwise specified, all tests were made with the antenna dipole 66" above ground.

Test #1: No modifications (Control)

Field Test:	AFC = 7.5 AGC = -5
Range:	In 120 m - Out 135 m using Audio Alarm
Range:	In 120 m - Out 120 m using Wrist Alarm

Test #2: 5000 μfd capacitors added across power supply

Field Test:	AFC = 15 AGC = 10 Heavy Winds
Range:	In 130 m - Out 145 m using Audio Alarm
Range:	In 130 m - Out 140 m using Wrist Alarm

Test #3: Addition of STC, transmitter pulse increased to 800 ns, dead zone increased to 50 meters, i.e., extending range gate to 220 meters

Field Test:	AFC = 15 AGC = -5
Range:	In 140 m - Out 155 m using Audio Alarm
Range:	In 140 m - Out 145 m using Wrist Alarm

Radar unit twisted 90° on axis to provide vertical polarization.
Dipole Height, 60" above ground
Range: In 130 m using Audio Alarm

Test #4: Processor Gain Increased 3 dB

Field Test: AFC = 5 AGC = -5
Range: In 170 m - Out 175 m using Audio Alarm
8 paces to alarm (30% detection level) at above range
Antenna raised 14" alarms at 85% level of above range

Test #5: Processor Gain Increased 1.5 dB

Field Test: AFC = 5 AGC = -5
Range: In 175 m - Out 190 m using Audio Alarm
Range: In 175 m - Out 190 m using Wrist Alarm
Antenna Raised 18"
Range: In 185 m - Out 210 m using Audio Alarm.

Test #6: Target Tests Across Charles River

(150 meters from radar to river bank on opposite side. Radar penetrates 5 meters of foliage on near side)

Field Test: AFC = 5 AGC = -5
Range: In - 20% at 155 m - Out 200 m using Audio Alarm
Radar moved back from radar 6 meters and raised 3 meters on knoll
Range: In 196 m - Out 203 m Audio Alarm
Range: In 193 m - Out 190 m using Wrist Alarm

5.8 EXTENDED DETECTION RANGE TESTS

Tests were conducted during the first week of September to determine the detection range of two LPSD's in various environments. All tests were made with the Audio Annunciator. The two units had the STC and sample and hold pulse moved out by 50 ns from the initial design setting. A description of the tests and the test summaries follow.

(1) Walking man in open field

Position of Target Rel. To Radar	UNIT #1 Max. Detection Range (meters)		UNIT #2 Max. Detection Range (meters)	
	IN	OUT	IN	OUT
Boresight	150	160	120	130
$+45^o$	115	125	95	107
$+90^o$	20	25	ND	ND
$+120^o$	ND	ND	ND	ND
$+150^o$	ND	ND	ND	ND
$+180^o$	ND	ND	ND	ND

ND = No Detection to within Four Meters

(2) Walking man with foliage surrounding radar

Position of Target Rel. To Radar	UNIT #1 Max. Detection Range (meters)		UNIT #2 Max. Detection Range (meters)	
	IN	OUT	IN	OUT
Boresight	80	75	85	85
$+90^{o}$	10	17	28	34
$+135^{o}$	20	20	28	24
$+180^{o}$	38	40	45	50

(3) Walking man with radar in clear looking into foliage

Position of Target Rel. To Radar	UNIT #1 Max. Detection Range (meters)		UNIT #2 Max. Detection Range (meters)	
	IN	OUT	IN	OUT
Boresight	80	90	89	99
$+90^{o}$	30	35	44	42
$+135^{o}$	45	45	48	48
$+180^{o}$	50	50	41	41

(4) Walking man with radar just inside foliage looking into clear

Position of Target Rel. To Radar	UNIT #1 Max. Detection Range (meters)		UNIT #2 Max. Detection Range (meters)	
	IN	OUT	IN	OUT
$+90^{o}$	13	15	5	6
$+135^{o}$	5	15	12	16
$+180^{o}$	5	15	4	4

The surveillance zone of a typical LPSD is shown in Figure 19. It was constructed from the data tabulated above.

5.9 SUMMARY OF FIELD TESTS ON UNITS DELIVERED

Table V summarizes the results of field tests taken on the LPSD's delivered to LWL. Since the program consisted of continuing experimentation, tests were made on some of the units several times.

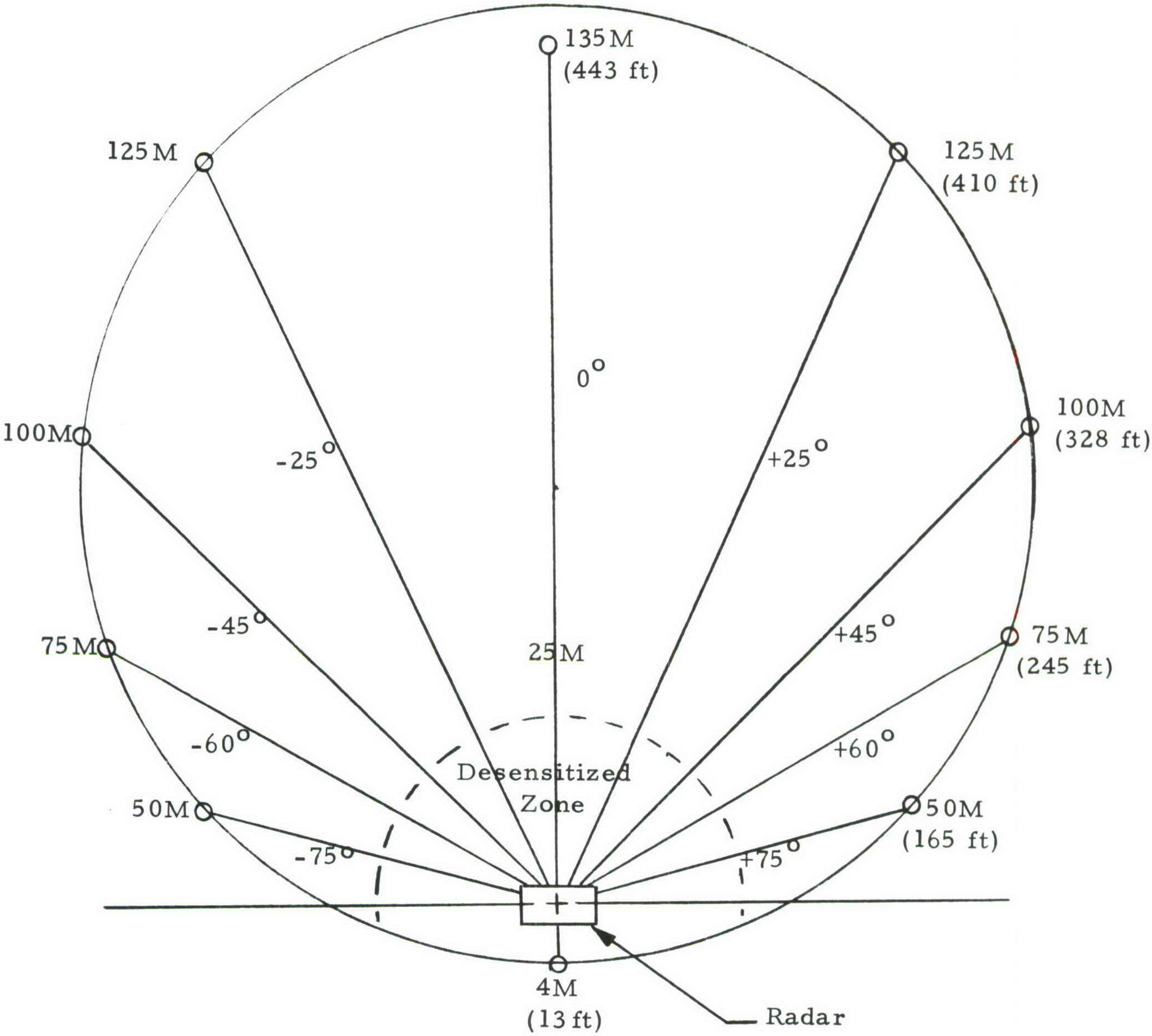


Figure 19: Typical Surveillance Zone of the LPSD
(For Upright-Man Target - Open Environment)

TABLE V

LPSD FIELD TEST SUMMARY SHEET

Test Date	Test Location	Wind Conditions	Test	Unit Ser.#	Range (m) In	Range (m) Out	AGC	AFC	Remarks
4/1/70	A	0-5 knots	F	2	125	125			Test of Unit Del. to LWL
4/1/70	A	0-5 knots	F	4	125	125			Test of Unit Del. to LWL
6/3/70	H	Moderate	F	4	140	130			Units tested prior to shipment to Ft. Hood & Vietnam
				5	124	130			
				6	130	135			
				7	135	130			
6/12/70	H	Mod-Low	F	4	125	130	15		Units for Ft. Hood & Vietnam
				5	110	115	10		
				6	112	155	20		
				7	140	156	10		
				10	120	125	12		
7/8/70	H	Lgt-Mod	W	1			12	5	
			F	1	125	110	0	5	With Beeper
			F	1	120	100	0	5	With Wrist Alarm
			W	2			20	5	
			F	2	120	130	10	2.5	With Beeper
			F	2	120	100	10	2.5	With Wrist Alarm
			W	4			20	7.5	
			F	4	145	155	0	7.5	With Beeper
			F	4	140	110	0	7.5	With Wrist Alarm
			W	5			20	5	
			F	5	120	130			With Beeper
			F	5	110	110			With Wrist Alarm
			W	7			25	7.5	
			F	7	130	125	10	5	With Beeper
			F	7	125	85	10	5	With Wrist Alarm

TABLE V (Continued)

Test Date	Test Location	Wind Conditions	Test	Unit Ser. #	Range (m) In	Range (m) Out	AGC	AFC	Remarks
			W	10			20	7.5	
			F	10	145	145	0	7.5	With Beeper
			F	10	130	110	0	7.5	With Wrist Alarm
7/10/70	H	Lgt-Mod	F	7	140	140	0	5	With Beeper
			F	7	130	85	0	5	With Wrist Alarm
			F	7	130	110	-5	5	With Wrist Alarm and 5000 μfd across power supply
7/13/70	H	Lgt-Mod	F	2	135	145	-5	0	With Beeper
			F	2	120	110	-5	0	With Wrist Alarm
			F	5	110	130	5	2.5	With Beeper
			F	5	105	135	10	5	With Beeper
			F	5	105	120	10	5	With Wrist Alarm
7/14/70	H	Moderate	F	2	130	105	0	7.5	With Wrist Alarm
			F	4	115	105	20	7-10	With Wrist Alarm
			F	5	110	105	10	2.5	With Wrist Alarm
			F	7	130	110	15	5	With Wrist Alarm
			F	10	125	90	5	5	With Wrist Alarm

Test Locations: A = Aberdeen Proving Grounds
H = Harvard Field

Test Condition: F = Walking Man in Field
W = Window Test

5.10 PRELIMINARY LPSD ENVIRONMENTAL TESTS

A series of environmental tests were conducted on LPSD prototype Serial Numbers EA-1 and EA-10 during the period June 4-10, 1970. These units were subjected to the following environments:

Environment	Unit
High Temperature	S/N EA-1
Low Temperature	S/N EA-1
Humidity	S/N EA-1
Barometric Pressure	S/N EA-1
Drop	S/N EA-1
Frequency Scan	S/N EA-1, S/N EA-10
Vibration Cycling	S/N EA-10
Water Immersion	S/N EA-10

Summary of Results

Temperature

a. 70° stabilized. Tests OK

b. 150°F, 2 hours. Tests OK

c. 20°F, 2 hours, Tests OK

Humidity

a. 125°F, 95% RH, 11 hours. Tests OK

b. 70°F, 95% RH, 8 hours. Tests OK

c. 125°F, 95% RH, 8 hours. Tests OK

d. 70°F stabilized. Tests OK

Barometric Pressure

a. 70°F stabilized. Tests OK

b. 8,000 feet, 20°F, 4 hours

c. 70°F stabilized. Tests OK

Drop Test, 3 Feet

a. Top surface. Tests OK

b. Baseplate surface. Tests OK

c. Corner opposite switches. Tests OK

d. Corner at switches. Malfunction

Unit draws 110-120 MA but will not alarm. Observed broken female connector at Card 1 Location in Processor housing. Connector repaired. Tests OK

e. Corner at nameplate. Tests OK

f. Corner at battery. Tests OK

Observed cracked weld at standoffs of RF Source housing and Video Amp housing. Flange of LPSD housing bent up 1/8th inch at corners. LPSD baseplate dented at corners.

Vibration

Frequency Scan - Z Axis

Malfunction. Caused by cracked solder on pins 4 and 5 of Adaptive Filter. Positive terminal on 6V battery found to be dented causing intermittent contact during self-test. The capacitor standoff on baseplate broken. These mechanical failures were believed to be caused in the drop tests.

Resonances were noted as follows:

a. 274 Hz, 4g - harnesses, Processor, semi-rigid coax

b. 411 Hz, 4g - Processor cover

c. 482 Hz, 4g - internal resonance, location unknown

(Note: At this point in the test program LPSD unit S/N EA-10 was substituted for S/N EA-1 and the testing continued.)

Frequency Scan - Z Axis

Tests OK. Resonances were noted as follows:

a. 203 Hz - loud buzzing, possibly in Processor or RF amp

b. 290 Hz - same as above, except louder plus baseplate-mounted capacitors vibrating

c. 475 Hz - Processor cover

Frequency Scan - X Axis

Tests OK

Frequency Scan - Y Axis

Tests OK. The following resonances were noted:

a. 95 Hz - baseplate-mounted capacitors vibrating because of sheared-off ground lug used as tie point

b. 175 Hz - Processor housing

Vibration Cycling

(Note: Vibration cycling was conducted in each of three axes according to the following specification: 5-8 Hz, 1.0g; 8-32 Hz, 1.5g scanning from 32 Hz to 5 Hz in 3 minute intervals for 20 minutes; 32-52 Hz, 2.5g scanning from 32 to 52 Hz at 4 minute intervals for 20 minutes; 52-500 Hz, 4g scanning from 52 to 500 Hz in 4 minute intervals for 20 minutes). X, Y and Z axis tests OK. Resonance in LPSD housing top surface at 200 Hz in Z axis vibration.

Water Immersion

Unit was submerged in 3 feet of water at 40°F for one hour and then transferred immediately to 3 feet of water at 80°F for one hour and then tested. LPSD housing removed, 12 grams of water drained from unit. All cards and surfaces covered with moisture, RF Source housing inside dry, Processor housing 1/16th inch water in base. Moisture in minus battery case and cover. Unit was dried thoroughly and tested OK.

5.11 ENVIRONMENTAL TESTS AND RESULTS

Environmental tests were carried out at Aerospace Research, Inc., and the Associated Testing Laboratory of Burlington, Massachusetts during June 1970. PPS-14 performance was monitored throughout the test program with the aid of ARI's PPS-14 Test Set. This test set, shown in block diagram form in Figure 20, performs a complete system

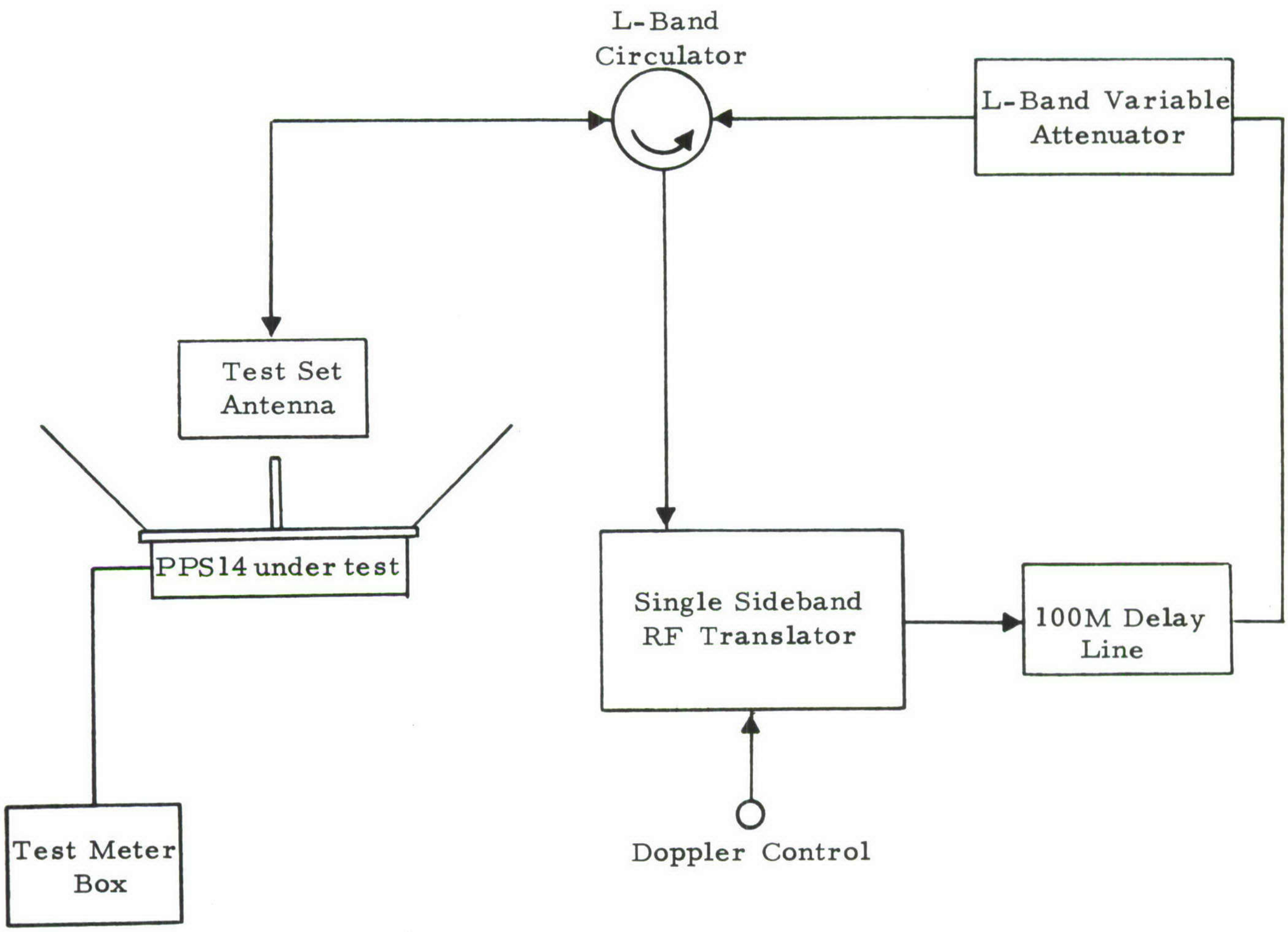


Figure 20: Block Diagram of PPS-14 Test Set

test by sampling the radar transmission, single-sideband converting it (at RF) by an adjustable Doppler frequency, delaying it, attenuating it, and sending it back into the radar's antenna at normal "receive" time, all of which normally occurs when the radar is viewing a moving target in the field. It therefore provides a good measure of PPS-14 performance. Small degradations in performance can clearly be observed, if and when, they occur on the test meter box included with the test set.

The following is a brief summary of the tests that were carried out and their results.

1. High and Low Temperature at Nominal and High Humidity

High Temperature - The PPS-14 was immersed in air at 140°F, and its temperature stabilized. It was operated at this elevated temperature for a period of two hours.

Low Temperature - The PPS-14 was immersed in air at 20°F and its temperature stabilized. It was operated at this low temperature for a period of two hours.

Humidity - The PPS-14 was immersed in air at 125°F and relative humidity of between 90 to 95 percent for a period of eight hours. The air temperature was then reduced to room temperature for a period of eight hours. The air temperature was then increased to 125°F and held there for eight hours. The PPS-14 was operated for a 30-minute period once every eight hours throughout this test. The following results were obtained.

Test	Results
70°F	Unit tested OK
140°F	Unit tested OK
20°	Unit tested OK
Humidity	Unit tested OK

2. Low Barometer Pressure at Low Temperatures

The PPS-14 was immersed in air at 20°F and its temperature stabilized. The simulated altitude was then changed from 0 feet to 8,000 feet at a rate of 2,000 feet per minute. The PPS-14 was held at this 20°F and 8,000 feet for 4 hours. The simulated altitude was then changed back to 0 feet at a rate of 2,000 feet per minute while the temperature was allowed to return to room temperature. The PPS-14 was operated just prior to and just after this Barometric Pressure Test.

Test	Results	Comments
Barometric Pressure	Unit tested OK	

3. Drop Tests to Concrete on Faces and Corners

The PPS-14 was allowed to free fall from a height of 3 feet onto a cement surface on the front face, the rear face, and each of its four baseplate corners. A total of 6 drops were performed.

Test	Results	Comments
Front Face	Unit tested OK	--
Rear face	Unit tested OK	--
Corner 1	Unit tested OK	--
Corner 2	Unit failed test	Found broken connector at card 1 in processor. Replaced, and unit then tested OK
Corner 3	Unit tested OK	--
Corner 4	Unit tested OK	--

After completion of drop tests, the unit was disassembled for inspection. Cracked welds were noticed at the source housing and video amplifier housing standoffs. The main flange of the PPS-14 housing was bent up 1/8th of an inch at four corners. PPS-14 baseplate dented slightly at four corners.

4. Vibration

The PPS-14 was vibrated from 5 to 32 cycles/sec at 1.5 g input for 15 minutes at a sweep rate of 3.1 minutes maximum to minimum frequency. The PPS-14 was then vibrated from 32 to 52 cycles/sec at 2.5 g input and from 52 to 500 cycles/sec at 4 g input for 1 hour at a sweep rate of 4.3 minutes minimum to maximum frequency. This test was conducted for each of 3 primary, mutually perpendicular, axes of the PPS-14. In addition, a frequency scan was performed on each axis. The PPS-14 was operated just prior to and just after each frequency scan and vibration cycle.

Tests	Results	Comments
Z-Axis Frequency Scan	Malfunction	Cracked solder on pins 4 and 5 of adaptive filter. Capacitor standoff on baseplate broken. Resonances noted as follows:

Tests	Results	Comments
Z-Axis Frequency Scan (continued)	Malfunction	274 Hz - harness, processor, semi-rigid coax 411 Hz - processor cover 482 Hz - internal resonance, location unknown Solder connections on adaptive filter were redone, and unit then tested okay Because of cracked welds caused by drop test, it was decided to substitute system EA-10 for EA-1 prior to continuing tests. This was done.
Z-Axis Frequency Scan (Repeat with Unit EA-10)	Unit Tested OK	Resonances: 203 Hz - internal 290 Hz - internal 475 Hz - processor cover
X-Axis Frequency Scan	Unit tested OK	Resonance - none
Y-Axis Frequency Scan	Unit tested OK	95 Hz ground lug holding baseplate mounted capacitors sheared off. Resonances: 175 Hz Processor housing capacitors bonded to baseplate with RTV.
X-Axis Vibration Cycle	Unit tested OK	--
Y-Axis Vibration Cycle	Unit tested OK	--
Z-Axis Vibration Cycle	Unit tested OK	--

5. Water Immersion

The PPS-14 was immersed to a depth of 3 feet in fresh water at a temperature of 40°F for a period of 1 hour, removed, and immediately immersed to a depth of 3 feet in fresh water at a temperature of 80°F for a period of 1 hour. This test was performed on unit EA-10 upon completion of vibration testing.

Tests	Results	Comments
Water Immersion	12 grams of water leaked into unit after soaked in water for two hours. Point of infiltration not apparent.	After removing water, unit tested OK.

CORRECTION OF DISCREPANCIES

It is currently envisioned that the discrepancies found during the environmental tests will be corrected as shown below:

Discrepancy	Plan for Correction
Need for more mechanical support for modules on Card 1 in processor	Rubber pads will be bonded to baseplate under Cards 1, 2, and 3 internal to processor housing.
Breaking of power supply, bypass capacitor mounting standoff	Capacitors will be cemented to baseplate.
Cracked welds	Present units will be inspected for weld integrity. On future units, the baseplate will be formed by a casting process, and the welding will no longer be necessary.
Water leakage	The source of this leak has not been determined. Additional tests will be conducted to find area of water infiltration and problem will be remedied.

The minor mechanical modifications needed to correct discrepancies in the systems for overseas shipment were programmed without affecting the planned schedule.

6.0 FINAL DESIGN AND FABRICATION SYSTEM SPECIFICATIONS

The LPSD system (see Figure 21) consists of the Radar Unit and a Wrist Alarm, as well as an Audio Alarm (not shown) for optional remote operation. A tripod and stretch cord (not shown) are included as accessories to facilitate mounting of the radar unit. A M-56 Field Pack is provided to carry the Radar Unit, the Remote Alarms, Stretch Cord, Spare Batteries, and Field Wire. The LPSD system, complete with batteries supplying 10 hours of continuous operation, weighs approximately 10 lbs.

The LPSD contains no high voltage circuits, and does not operate at sufficiently high power levels to be injurious to, or endanger the lives of personnel handling the equipment.

A block diagram of the LPSD is shown in Figure 22. The component units and specifications for these units are described in the following sections of this report.

6.1 ANTENNA

The antenna reflector is a three segment fold-out, which when opened to its operating position, approximates the curvature of a parabola with a 4" focal length. The feed element is a dipole printed on a fiberglass card. It folds flat when not in use. The two reflector flaps fold over the dipole to form the cover for the unit.

A photograph of the Radar with the reflector plates extended to its operating position is shown in Figure 23. The dipole is also shown in its operating position and is horizontally polarized.

The operating characteristics and specifications for the antenna are as follows:

ELECTRICAL

1. Power - 15 mW rms, 60 mW peak
2. Frequency - 1.25 GHz $\pm$ 5 MHz
3. Vertical beamwidth - 46° maximum
4. Horizontal beamwidth - 72° minimum
5. VSWR - 1.4 maximum
6. Front/Back ratio > 25 dB
7. Front/Side ratio > 15 dB

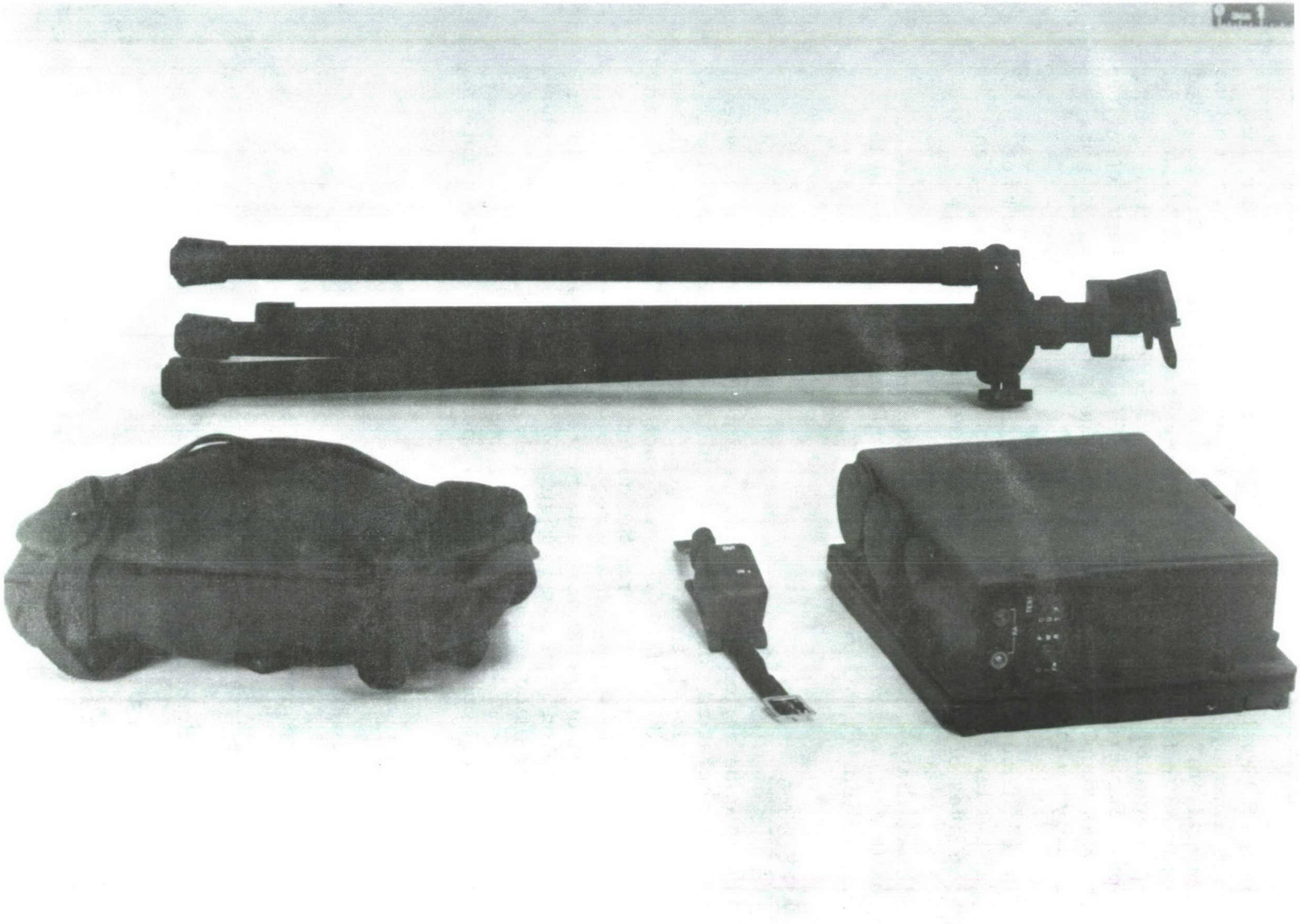


Figure :1: AN/PPS-14 Radar Unit with Tripod, Wrist Alarm, and Field Pack

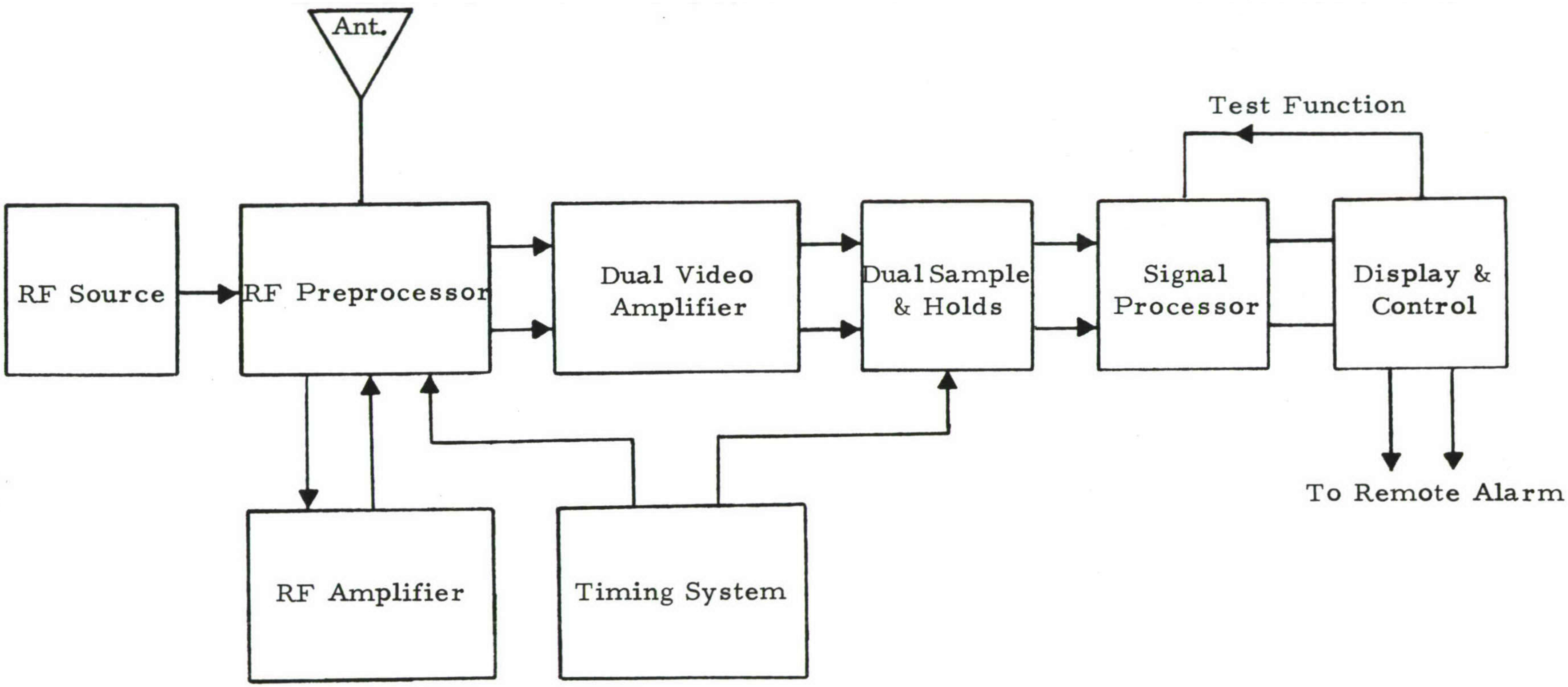


Figure 22: LPSD Block Diagram; Radar Unit

Figure 23: Radar Unit with Antenna in Operating Position

8. Gain loss due to rain and other environmental conditions > 2 dB

ENVIRONMENTAL

1. Temperature: -40° C to $+70^\circ$C

2. Humidity: 95% at 50°C for 24 hours reduced to 25°C before checking for degraded operation

3. Shock: Three feet fall onto cement surface on each face and corner

4. Vibration: Three-axis vibration check:

   5 to 32 cps at 1.5 g
   32 to 52 cps at 2.5 g
   52 to 500 cps at 4.0 g

PHYSICAL CHARACTERISTICS

1. Dimensions are not to exceed 8" x 6" x 1/2" when not extended.

2. Connector from antenna to Radar Unit to be watertight.

6.2 RF SOURCE

A crystal oscillator followed by an appropriate multiplier chain is required to provide 10 mW transmitting power. A block diagram of the LPSD source is shown in Figure 24.

The overtone crystal oscillator is followed by a tripler. The next stage is a frequency doubler which follows a buffer stage. The doubler is then followed by two stages of amplification. The last stage is a varactor diode doubler which provides the final L-band signal. The output of the source goes to a coaxial "Tee" connector. One leg of the "Tee" provides LO signal for the mixers while the other leg goes to the preprocessor to be switched into the antenna during the transmit period.

The load that the pulsed Doppler radar will present to the source will vary in VSWR from about 1.25 to some arbitrarily high number. A graph of the behavior of the load VSWR is shown in the sketch below. The VSWR goes from some small value to an open circuit when the circuit is switched.

The multiplier chain should represent enough isolation to VSWR changes in the load so that the crystal oscillator is not pulled more than one-half a cycle over the duration of a 300 ns period.

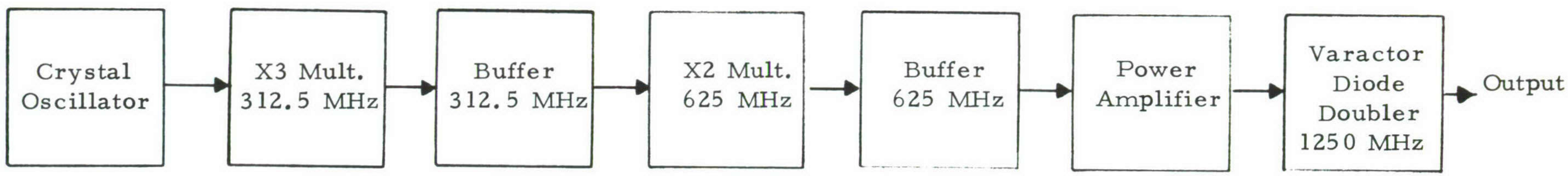
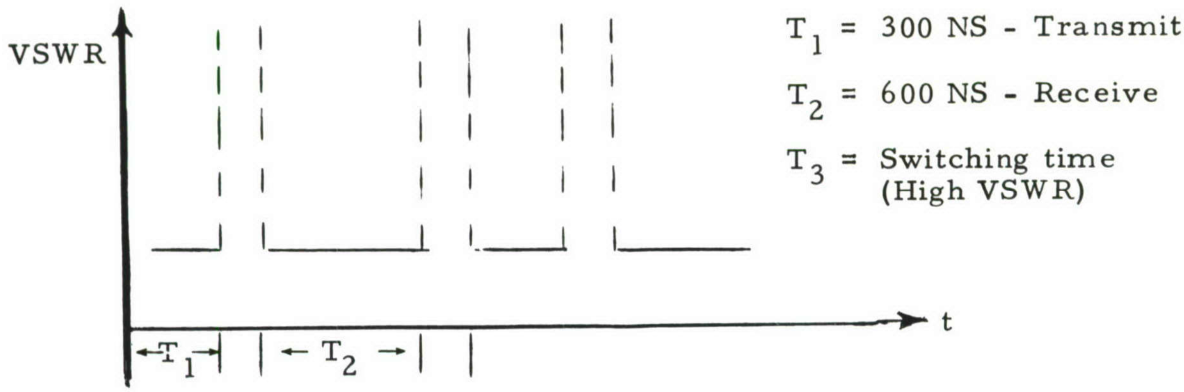


Figure 24: CW Transmitter



The following specification applies to the RF source:

ELECTRICAL

1. Output power > 10 mW.
2. Frequency = 1.25 GHz.
3. The multiplier chain is to be chosen by the circuit designer that best serves the electrical requirements.
4. Harmonic and sub-harmonic spurious content is to be greater than 10 dB below desired signal.
5. DC voltage = + 6 V $\pm$ 0.7 volts (5.3 to 6.7)
6. DC current $\leq$ 30 mA.
7. Overall efficiency > 8%.
8. Frequency drift < Lowest Doppler frequency deviation.
9. The circuit is to be adequately decoupled so that no spurious signals appear on the DC lines supplying the source.

ENVIRONMENTAL

1. Temperature: -40° to + 70°C. $\pm$ 1 dB deviation max.
2. Humidity: 95% at 50°C for 24 hours reduced to +25°C before checking for degraded operation.

3. Shock: Three feet fall onto cement surface on each face and corner.

4. Vibration: Three-axis vibration check:

   5 to 32 cps at 1.5 g

   32 to 52 cps at 2.5 g

   52 to 500 cps at 4 g

PHYSICAL CHARACTERISTICS

1. The source must be constructed as compact as possible and must fit into a RF-tight box.

2. Connector - OSM female.

6.3 RF PREPROCESSOR

The RF Preprocessor contains switching networks, isolation and signal splitting hybrids, and the double balanced mixers (DBM). The components of the Preprocessor is shown in Figure 25.

The Preprocessor consists of six (6) sub-assemblies, interconnected by a fifty (50) ohm system, such that the two signal outputs are within 0.5 dB in amplitude and have a quadrature error not exceeding plus or minus 3^{o} in the DC to 200 Hz range or in the 150 kHz to 20 MHz range.

OPERATING ENVIRONMENTAL CONDITIONS

1. Humidity: 95% at $50^{o}C$ for 24 hours reduced to $25^{o}C$ before checking for degraded operation.

2. Shock: The unit is to operate after the system has been dropped three feet onto a concrete surface with the unit mounted in the radar unit.

3. Vibration: Three-axis vibration check at 30 to 50 cps at 2.5 g, 50 to 500 cps at 4 g, three hours each, 5 minute sweep.

4. Temperature Range: $-20^{o}C$ to $+70^{o}C$.

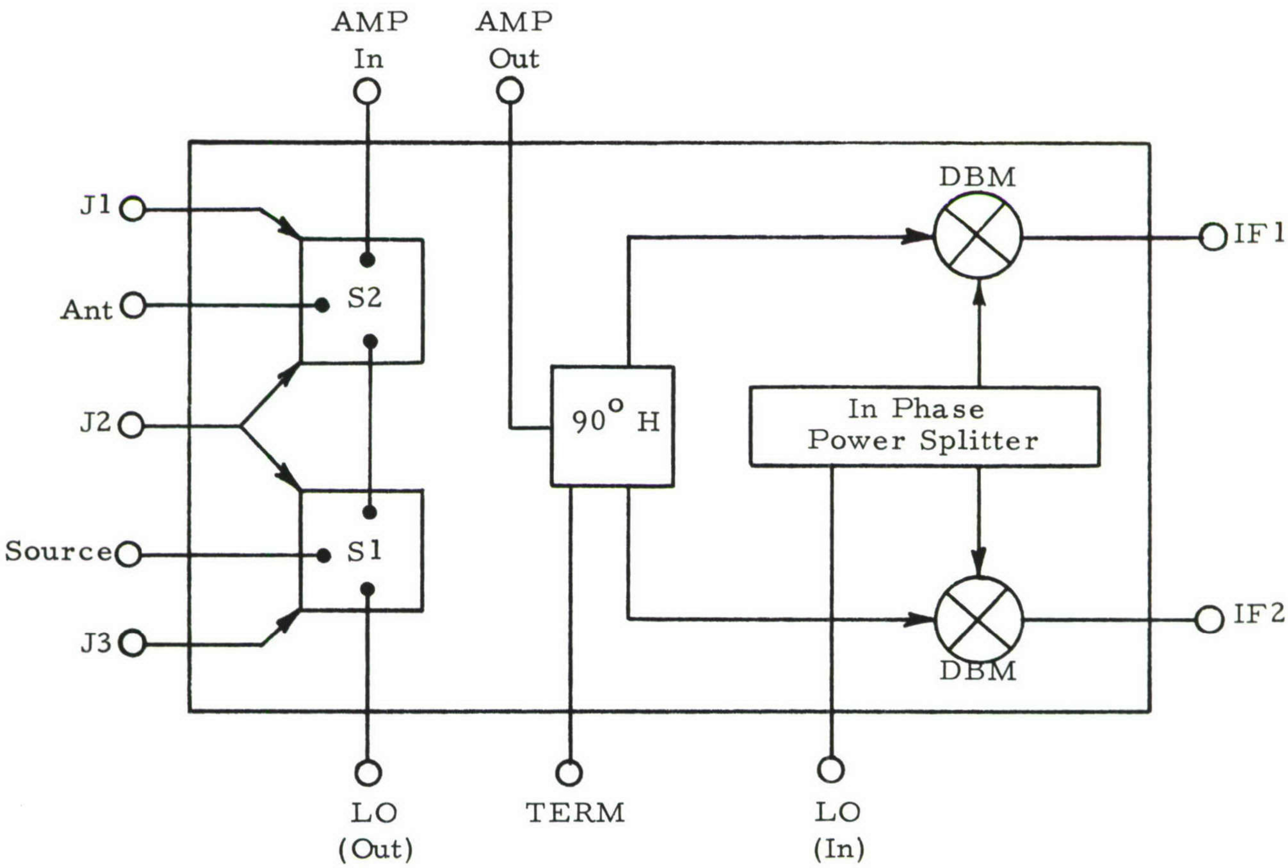


Figure 25: RF Preprocessor

PHYSICAL CHARACTERISTICS

1. RF Component Box

   The RF Component Box will house all of the components. The physical dimensions are not to exceed 2" x 3" x 0.5", not including the connectors. Material should be of a type that resists corrosion and must be RF-tight.

2. Connectors

   Miniature 3 MM connectors on all units.

3. Each box will bear labels and ARI Part Number.

6.4 RF AMPLIFIER

During the receive mode, the antenna is connected to the RF amplifier, which provides a gain of 10 dB. The amplified signals are returned to the mixers in the Preprocessor.

The RF amplifier is required to provide high dynamic range simultaneously with low front-to-back transmission ratios. Low front-to-back ratios can usually be achieved by (a) high isolation transistors, (b) neutralization, and (c) ground base configurations.

The specifications for the RF Amplifier are as follows:

1) Center frequency = 1.25 GHz
2) Bandwidth ≥ 50 MHz
3) Gain ≥ 9 dB → 12 dB
4) Reverse attenuation ≥ 30 dB
5) Input VSWR ≤ 1.25
6) Output VSWR ≤ 1.25
7) 1 db desensitization signal ≥ 200 mv RMS max. input signal/ 50 Ω at output
8) DC volts = + 6 V ± 15%
9) DC current ≤ 30 ma
10) Noise figure ≤ 7 dB
11) Number of stages - 2

ENVIRONMENTAL

1) Temperature = $-40^{\circ}C$ - $+70^{\circ}C$
2) Humidity - 95% at $50^{\circ}C$ for 24 hours reduced to $25^{\circ}C$ before checking for degraded opeation
3) Shock - Three feet free fall onto cement surface on each face and corner
4) Vibration - Three axis vibration check

   5 to 32 Hz at 1.5g

   32 to 52 Hz at 2.5g

   52 to 500 Hz at 4g

PHYSICAL CHARACTERISTICS

1) The RF-tight box (allowing for holes for trimmer adjustments) should be as small as possible and made from a material that is corrosion resistant
2) OSM connectors (female)
3) Mounting to be such that two amplifiers can be readily stacked in series

6.5 DUAL VIDEO AMPLIFIER AND SAMPLE AND HOLD MODULES

The mixer outputs from the Preprocessor are amplified 36 dB in two identical video amplifiers. Combined in the same module are dual sample and hold circuits. The two quadrature sub-audio outputs of this module are then transferred to the Signal Processor.

The detailed specifications for the Dual Video Amplifier and the Sample and Hold Module are as follows.

VIDEO AMPLIFIER

Number of Channels	2
Input Impedance	50 Ω
Input	AC coupled after 50 Ω termination
Gain Each Channel	Variable from 20 dB to 46 dB
Bandwidth	100 kHz - 30 MHz
Output Impedance	$<$ 50 Ω
Output Swing	4.0 v p-p

SAMPLE AND HOLD MODULE

Sample Rate	220 kHz $\pm$15%
Pulse Input Level	Positive going pulse referred to ground. Amplitude > 1 V DC
Pulse Amplifier Input Impedance	2.0 K in parallel with 50 pf
Output Impedance	< 1.0 Ω
Output Swing	$\pm$ 2 V
Droop	0.5 mV maximum
Bandwidth	DC to 450 Hz

OVERALL VIDEO AND SAMPLE AND HOLD MODULE

Noise referred to input (Gain 36 dB)	2.5 μV rms
Power Supply Rejection (Gain 36 dB)	20 dB measured at output
Voltage	$\pm$ 6 V $\pm$ 15%
Current	40 ma per supply
Phase shift between channels	CH1 = CH2 $\pm$ 2° over the frequency band of 0 to 40 Hz

ENVIRONMENTAL

Temperature Range: - 40°C to + 70°C

Humidity 95% at 50°C for 24 hours reduced to 25°C before checking for specification conformance

Shock three foot free fall

Vibration - three axis vibration check:

5 to 32 Hz at 1.5 g

32 to 52 Hz at 2.5 g

52 to 500 Hz at 4.0 g

PHYSICAL CHARACTERISTICS

Circuit mounted on PC card module in RF tight box

6.6 SIGNAL PROCESSOR

The Signal Processor is a balanced adaptive dual velocity channel signal system, and is composed of three plug-in cards.

a. Card 1 amplifies the two quadrature inputs and filters each input in one of two cutoff-frequency tracking voltage controlled high pass filters. The second module on this card takes the two inputs and phase shifts one 90° with respect to the other. The last module combines the two quadrature Doppler signals in such a way as to separate incoming target data from outgoing data. This module also provides two dual automatic gain control (AGC) amplifiers, one for incoming and one for outgoing targets. The output of Card 1 represents all Doppler data in the frequency band of interest. Card 2 operates on data in the lower half band of interest, while Card 3 will operate in the upper half of the band of interest.

b. Card 2 contains circuitry which amplifies low velocity target data. At its output are integrator, threshold detector and driver circuits for annunciating targets to the operator. In addition, a circuit is present for driving the control for the dual adaptive filter on Card 1.

c. Card 3 contains circuitry which amplifies high velocity target data. At its output are an integrator, threshold detector and driver circuits for annunciating targets to the operator. In addition, a circuit is present for driving the control for the gain of the dual AGC module on Card 1.

The LPSD operates from batteries, and accordingly, the power supplies are poorly regulated. Current requirements should be kept to a minimum to conserve on battery life.

The specifications for the Signal Processor is as follows.

INPUT SIGNAL CHARACTERISTICS

1. Sensitivity: The processor shall alarm on in-band CW quadrature signals of 0.1 mV p-p. Quadrature signals are defined as two signals to be within 1.5 dB in amplitude, and $\pm 5^{\circ}$ in phase, if the video amplifier output is within 1 dB.

2. Maximum Signal Handling

   All in band signals up to and including 40 millivolts peak-to-peak shall cause the processor to alarm.

3. Clutter Handling Capability

a. The processor shall not alarm when driven by a .250 volt peak-to-peak CW signal applied to each input with the same phase at any frequency below 0.5 Hz

b. The processor shall not alarm when driven by a 4.0 millivolt peak-to-peak CW signal applied to each input with the same phase at any frequency between 0.5 and 60 Hz.

4. Subclutter Visibility

The processor shall alarm on an in band quadrature signal, whose amplitude is equal to or more than 0.25 millivolts peak-to-peak in the presence of .250 volts peak-to-peak CW signal applied in phase to each input.

5. Bandwidth

An in band signal is defined as one whose frequency is between 1 and 40 Hz.

OUTPUTS

The processor shall provide two wires to annunciate and/or define target detection.

1. Incoming Target

This wire shall rest at -4.0 $\pm$ 0.2 volts when no targets have been detected. Upon detection of an incoming target, it shall rise to + 5.0 volts and be able to provide 30 ma of current. It shall remain up for a minimum of 2 seconds.

2. Outgoing Target

This wire shall normally rest at -4.0 $\pm$ 0.2 volts when no targets have been detected. Upon detection of an outgoing target it shall rise to + 5.0 volts and be able to provide 30 ma of current. It shall remain up for a minimum of 2.0 seconds.

VELOCITY CHANNELS

There shall be two velocity channels. The first channel will respond to inputs between 1 and 6 Hz. The second channel will be from 6 to 40 Hz.

1. Several Filter Characteristics

a)	Type	Butterworth
b)	Cutoff frequency accuracy	$\pm$ 5%
c)	Gain accuracy	$\pm$ 0.5 dB
d)	Stability	$\pm$ 0.01 dB/^{o}C
e)	Tracking capability	$\pm$ 0.003 dB/^{o}C
f)	Maximum in band ripple	$\pm$ 0.2 dB

2. Low Velocity Channel

a) The low velocity channel shall be from 1 to 6 Hz. Its time on target integrator shall require a target moving at a speed of 2 Hz to cause an alarm after 15 feet of distance has been traversed.

b) A dual adaptive filter whose cutoff frequency may be varied between 1 and 10 Hz shall be provided. It shall be a dual 5-pole filter. This filter shall automatically adjust itself to reduce the clutter in this low frequency channel to a value which will not permit false alarms. The time constant of the control loop for this dual adaptive filter shall be 149 sec. /volt.

High Frequency Channel

a) The high frequency channel shall be from 6 to 40 Hz. Its time on target integrator shall require a target moving at a speed of 8 Hz to cause an alarm after six feet of distance has been traversed.

AGC

The processor shall include an automatic gain control device. This device shall be capable of changing the gain of the processor a minimum of 34 dB. The gain control shall be effective on both the low and the high velocity channels. It shall be controlled by the clutter residue in the high velocity channel. The tracking accuracy of this dual channel (upper side band and lower side band) shall be within $\pm$0.5 dB. The time constant of the AGC loop shall be 22 sec. /volt.

ENVIRONMENTAL

1. Temperature Range— -40^{o} C to +70^{o}C
2. Humidity - 95% at 50^{o}C for 24 hours reduced to 25^{o}C before checking for degraded operation.

3. Shock - Three foot free fall onto cement surface on each face and corner.

4. Vibration - Three axis vibration check:

   5 to 32 Hz at 1.5g

   32 to 52 Hz at 2.5g

   52 to 100 Hz at 4.0g

PHYSICAL CHARACTERISTICS

1. Circuit mounted on three PC card modules
2. Circuit to be mounted in RF tight box
3. Feed-through interconnections with system

SUPPLY VOLTAGE

The processors must meet all the requirements of this specification when powered by a pair of batteries.

Voltage a) +5.3 to + 6.7 V dc

b) -5.3 to - 6.7 V dc

The two supplies will equal each other within 0.5 volts.

Power supply rejection > 66 dB.

6.7 TIMING SYSTEM

System timing is controlled by timing and driver circuits. A block diagram of the timing circuit is shown in Figure 26.

The heart of the timing circuit is a bistable multivibrator oscillating at 220 kHz. The output of the oscillator feeds a complimentary emitter follower which controls the antenna transmit/receive switch in the Pre- Processor. The multivibrator also drives a delay circuit. The delayed output of the transmitter pulse is used as the trigger for the Sample and Hold circuits. The time between the turn-off of the transmit pulse and the sample and hold trigger forms a zone of reduced sensitivity in the immediate vicinity of the radar. The timing waveforms shown in Figure 27 show a delay of 100 nanoseconds (T_5 - T_1) before the receive gate is opened. This creates a desensitization zone.

The timing and driving circuit requirements to drive the RF diode switches, and the sample and hold circuits have to be built per the following specifications.

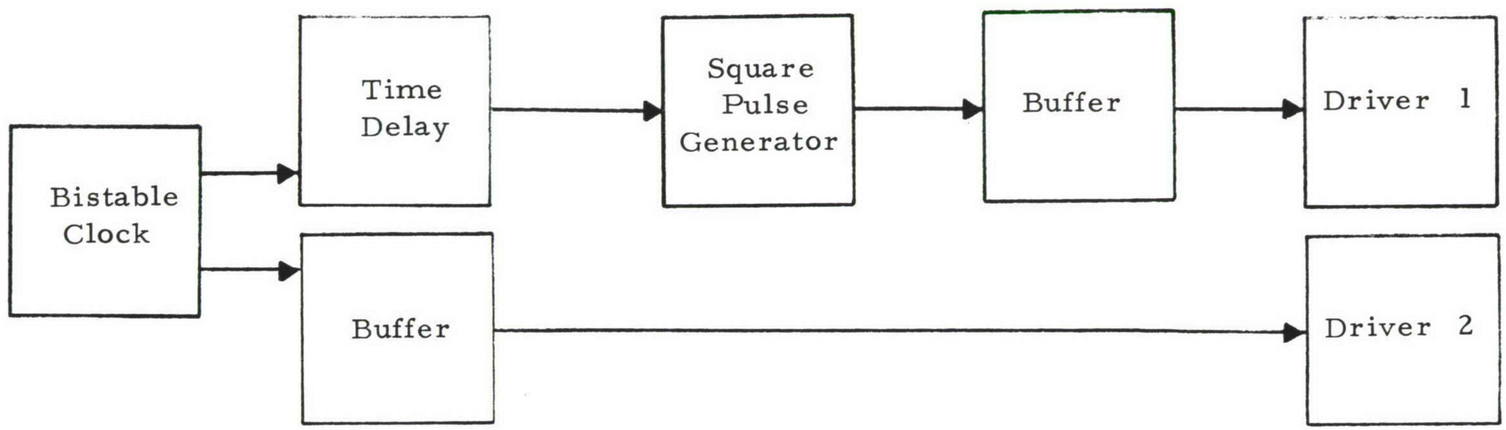
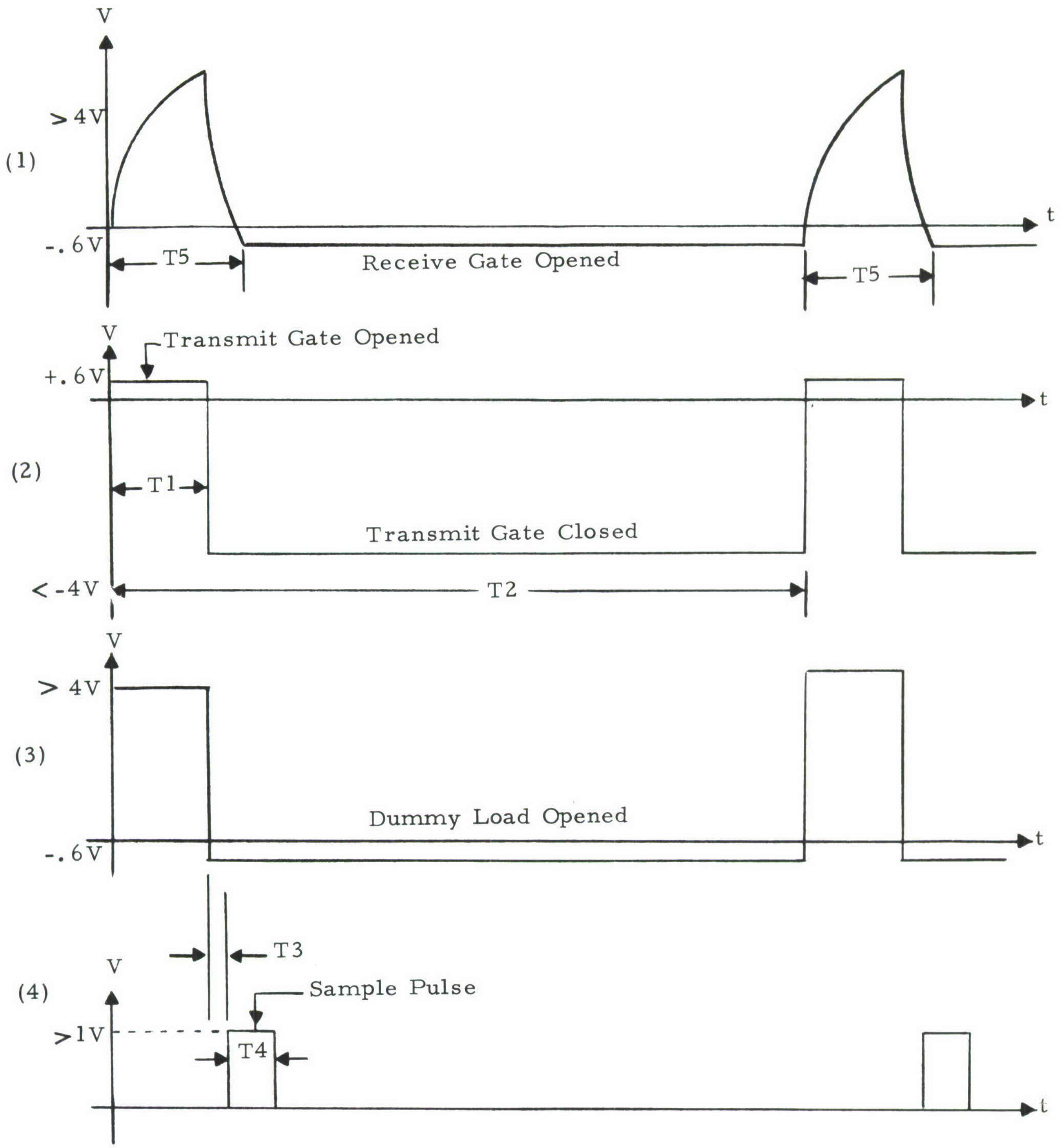


Figure 26: Timing System



T1 = 650 nsec ±10%
T2 = 4.5 μsec ±10%
T3 = 100 nsec ±10%
T4 = 300 nsec ±10%
T5 = 750 nsec ±10%

All rise and fall times
[10% to 40% |V|] ≤30 nsec

Figure 27: Timer and Driver Circuit; Timing Waveforms

1) Input Specifications

(a) Current $\leq$40 ma at -6.0 Vdc $\pm$ 10%

(b) Current $\leq$25 ma at +6.0 Vdc $\pm$ 10%

2) Output Specification

(a) Output (1) to be able to drive 2 RF diode switches (1 ma $\leq$ 1 $\leq$ 3 ma per switch)

(b) Output (2) to be able to drive 4 RF diode switches (1 ma $\leq$ 1 $\leq$ 3 ma per switch)

(c) Output (3) to be able to drive 2 RF diode switches (1 ma $\leq$ 1 $\leq$ 3 ma per switch)

(d) Output (4) to be able to drive sample and hold circuit

(e) See Figure 27 - Timing Waveforms

3) Environmental

(a) Temperature range -40°C → +70°C

(b) Humidity - 95% at 50°C for 24 hours reduced to 25°C before checking for degraded operation

(c) Shock - When mounted in system, must operate after system falls freely three feet onto cement surface

(d) Vibration - Three axis vibration check:

5 to 32 Hz at 1.5g

32 to 52 Hz at 2.5g

52 to 500 Hz at 4g

4) Physical Characteristics

(a) Circuit mounted on PC card module

(b) Circuit to consume no more than 2" x 2-3/4" x 5/8" volume

(c) Plug-in interconnections with system

6.8 DISPLAY AND CONTROL UNIT

The Display and Control Unit are an integral part of the LPSD, and contain the following control and display functions.

Item	Function
PWR - power switch	Turn LPSD "ON" or "OFF"
TEST - test switch	Center off spring return switch to test the radar.
Test Indicator	Two recessed light-emitting indicators that show target direction. They are mounted above the test switch, each above its appropriate designation (IN, OUT), and will indicate when the test switch is energized. The appropriate light will come on when a target is detected.
RA - binding post	A pair of binding posts are mounted at the top of the control panel area which are used to attach wires for either remote alarm.

A photograph showing the operator energizing the test circuits, and attaching wires to the binding posts are shown in Figures 28 and 29.

Remote alarms are attached to binding post RA by Army Field Wire (WD-1/TT). To facilitate hook up in the dark, the wire should be fed into each terminal through a hole located in the top of the control panel shroud directly above. The terminals are polarized so be certain that terminal #1 of the Radar Unit is tied to terminal #1 of the remote alarms. Terminal #1 of both remote alarms and the radar unit have raised bumps at the ends of the terminals to aid in terminal identification in the dark.

The Wrist Alarm, Model WA-6, is a vibrating silent remote-alarm indicator designed to be strapped to the operator's wrist.

The Remote Alarm consists of an audio tone with a volume control. It also lights target indicator "IN" or "OUT". The dimensions of this alarm are not to exceed 1 1/2" x 1 1/4" x 2", and the weight is 4 oz.

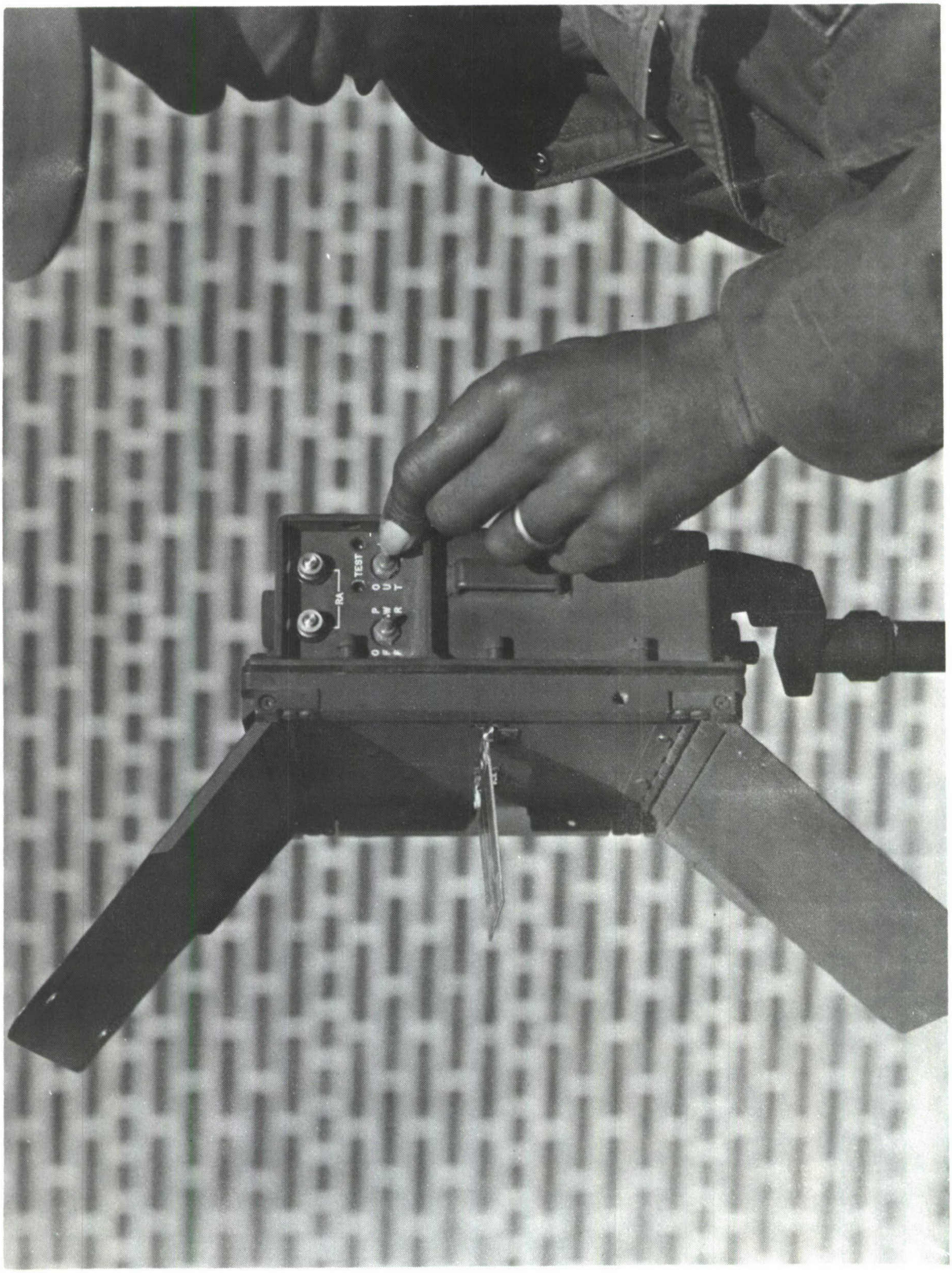


Figure 28: Operator Energizing Test Circuit

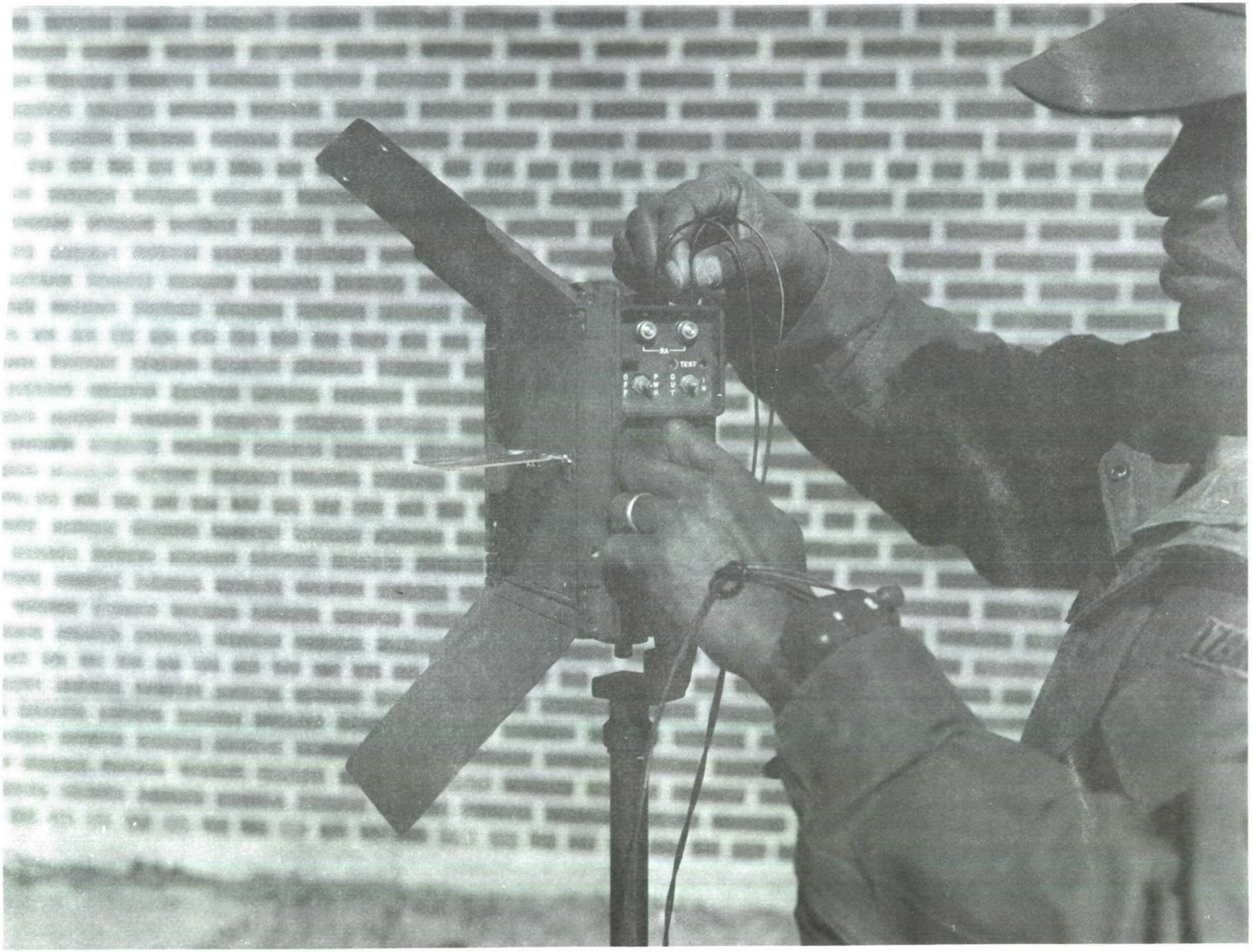


Figure 29: Operator Connecting Field Wire to Binding Posts

The specifications for the Wrist Alarm are described below.

SPECIFICATIONS

Item	Characteristics
Power Requirements	Nominal Operating Voltage Range 6 - 15 Volts DC
Outputs	In/Out Solid State Lamps Vibrating Tactile Stimulator
Dimensions	
Height	5 cm (2 in.)
Width	6.4 cm (2-1/2 in.)
Depth	6.4 cm (2-1/2 in.)
Weight	145 g (5 oz.)
Ambient Temperature Range	0 - +55°C

OPERATION

When voltage is applied to binding post, Wrist Alarm will indicate.

When positive voltage is applied to binding post #1, "OUT" lamp will light and Wrist Alarm will vibrate.

When positive voltage is applied to binding post #2, "IN" lamp will light and Wrist Alarm will vibrate. The Wrist Alarm (WA-6) will operate from any battery or electronic equipment capable of supplying 20 mA at 9 V DC.

6.9 CIRCUIT LAYOUTS AND SCHEMATICS

The location of major components and subassemblies of the LPSD Radar Unit, AN/PPS-14 are shown in Figure 30. The schematics for each of the major subassemblies are shown in Figures 31 through 35.

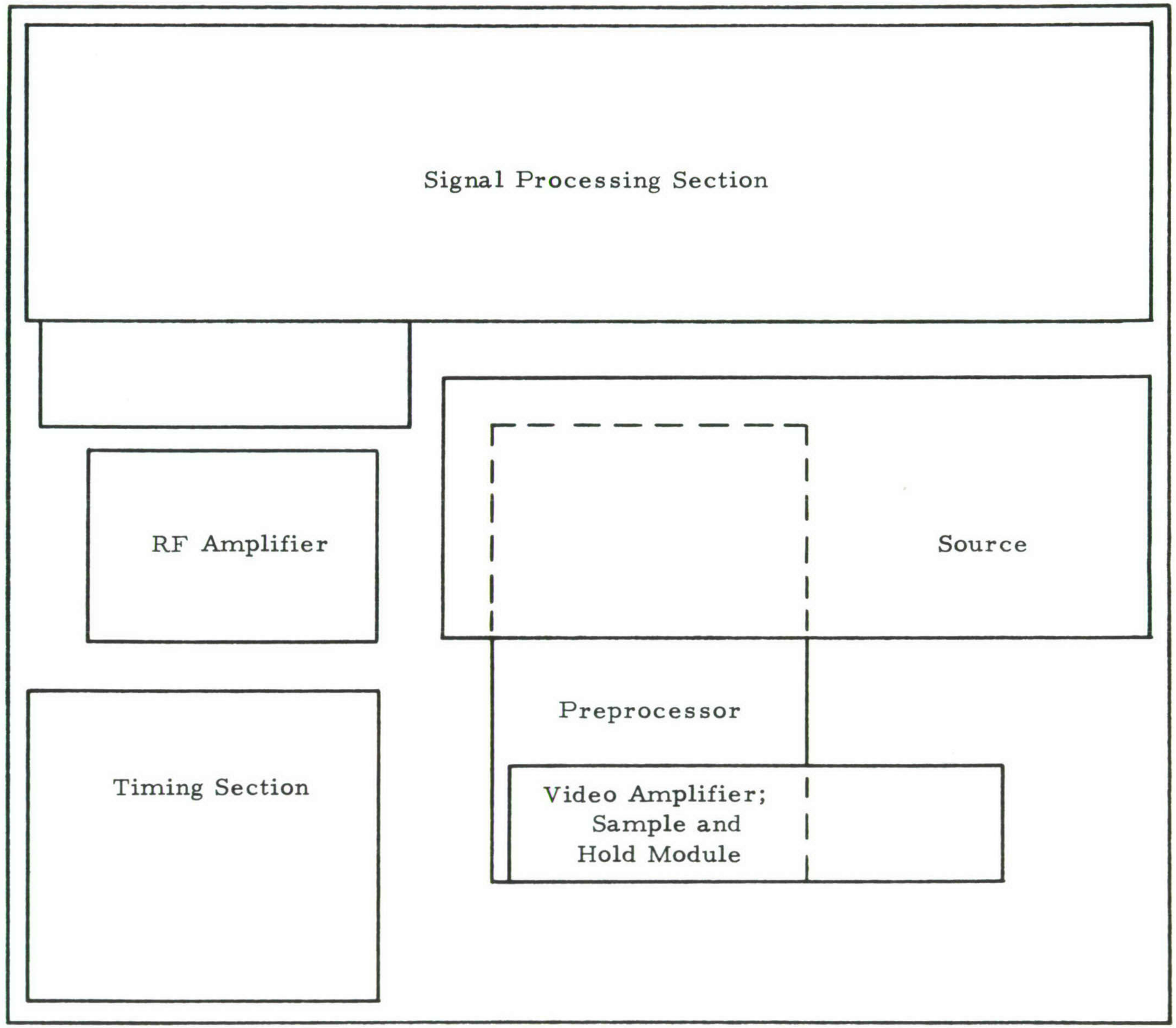
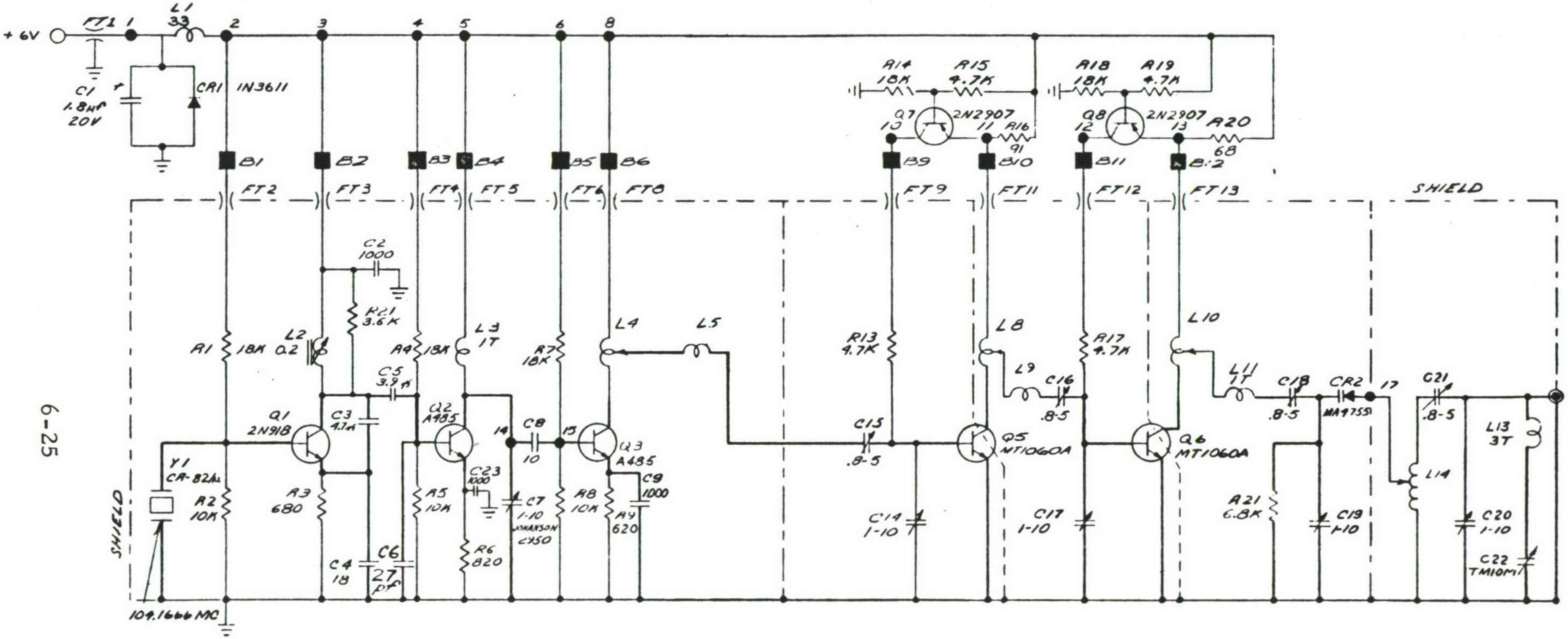


Figure 30: Major Assembly Locations



NOTES:

UNLESS OTHERWISE SPECIFIED:

1. ● DENOTES PIN CONNECTION.
2. ALL HEAVY LEADS ARE TO BE AS SHORT AS POSSIBLE.
3. ALL VARIABLE CAPACITORS ARE JOHANSON NO. 4140 TYPE.
4. ALL RESISTORS IN OHMS, 1/4 WATT, ±10 %.
5. ALL CAPACITORS IN PICOFARADS.
6. ALL INDUCTORS IN MICRO-HENRIES
7. ■ DENOTES FERRITE BEADS.

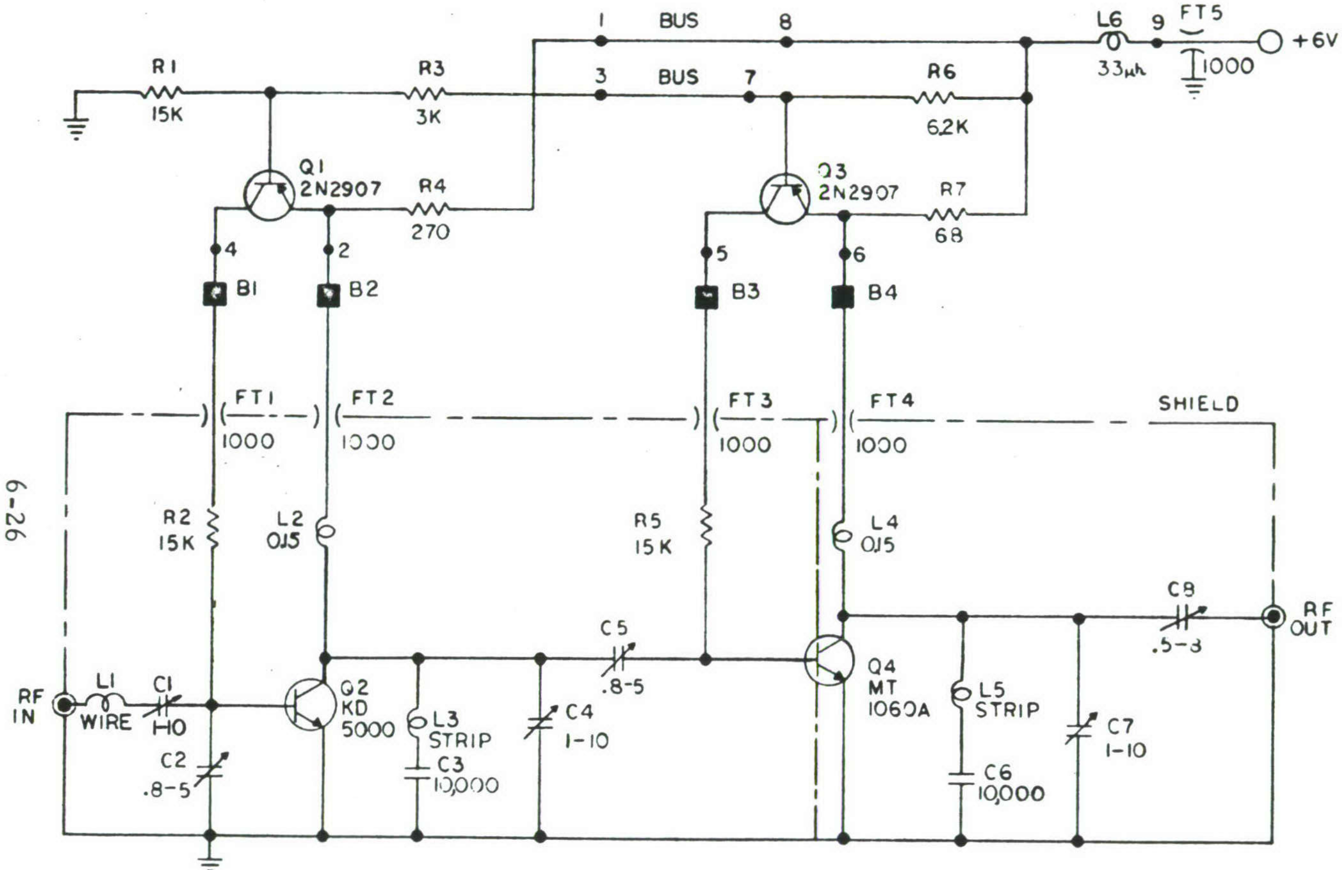
REV	REVISIONS
A	ECO#586
	I.S. 3-24-70
B	ECO#618
	2.2.P. 5-4-70

Figure 31

1250 MHz CRYSTAL CONTROLLED SOURCE SCHEMATIC LPSD

AEROSPACE RESEARCH INC. BOSTON, MASS.

D 255-3006 B



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   A. RESISTOR VALUES ARE IN OHMS
   B. CAPACITOR VALUES ARE IN PICOFARADS
   C. ALL INDUCTOR VALUES ARE IN MICROHENRIES
2. ■ DENOTE FERRITE BEADS.

Figure 32

DWG. NO. 355-3005	REVISIONS		
SYM.	DESCRIPTION	DATE	APPROVAL
A	PER ECO # 606		

LIST OF MATERIALS

DRAWN D.J. 8-14-69

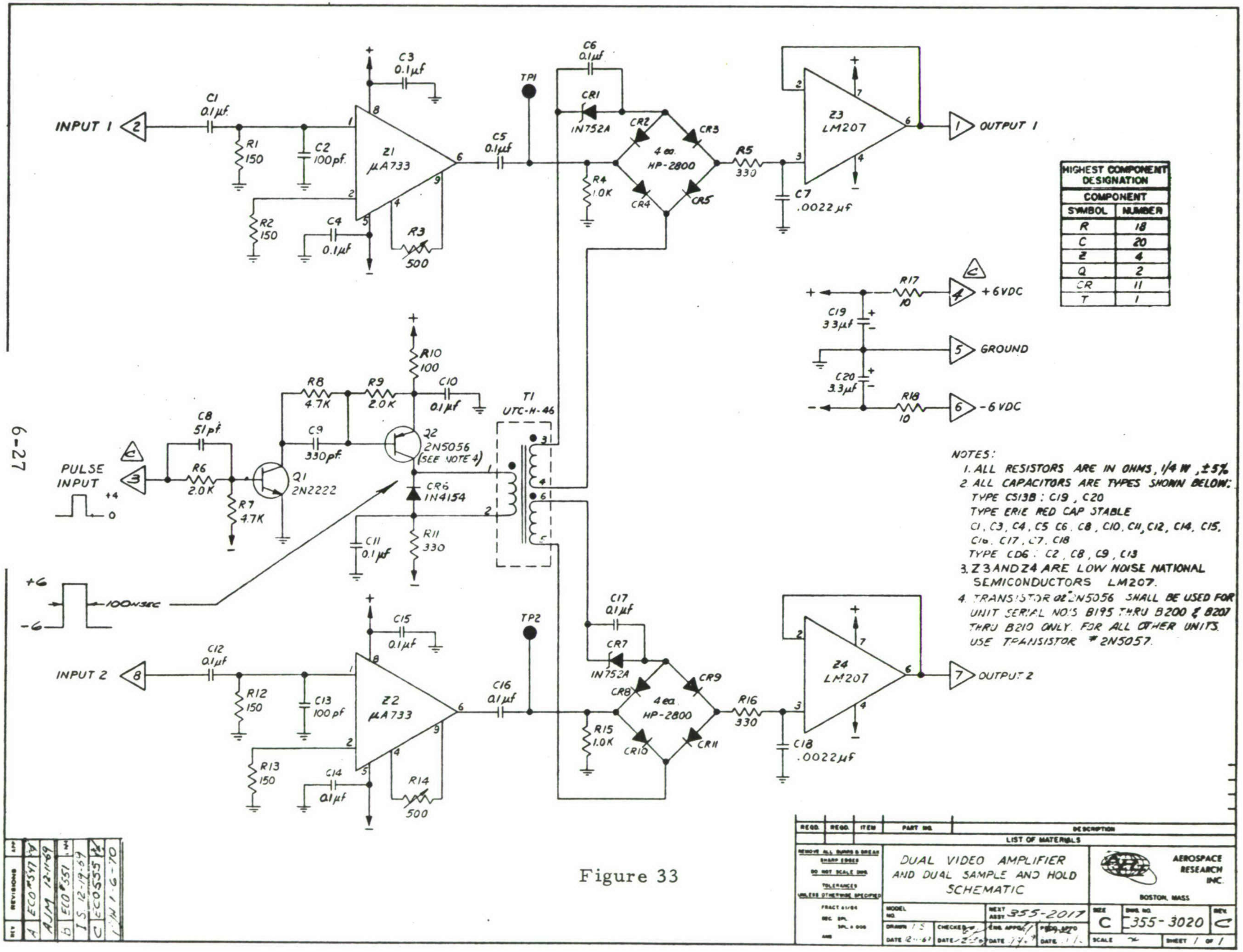
CHECKED

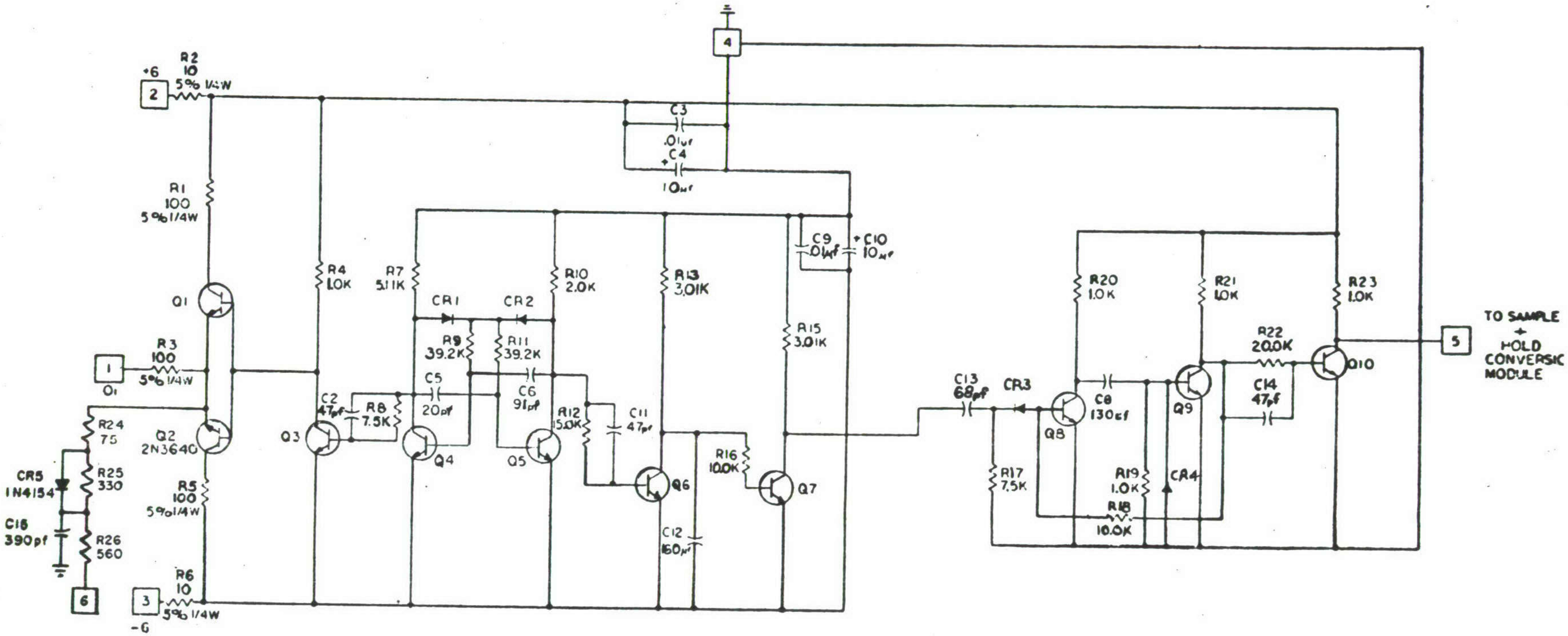
PRODUCT ENG. APPD G.K.

SCHEMATIC, R.F. AMPLIFIER

AEROSPACE RESEARCH INC. BOSTON, MASS.

SIZE C DWG. NO. 355-3005 REV. A


INPUT 1
INPUT 2
PULSE INPUT
+4
0
+6
-6
100NSEC
OUTPUT 1
OUTPUT 2
+6VDC
GROUND
-6VDC
Z1 μA733
Z2 μA733
Z3 LM207
Z4 LM207
Q1 2N2222
Q2 2N5056 (SEE NOTE 4)
CR6 1N4154
T1 UTC-H-46
TP1
TP2
4 ea. HP-2800
CR1 1N752A
CR7 1N752A
C1 0.1μf
R1 150
C2 100pf.
R2 150
C3 0.1μf
C4 0.1μf
R3 500
C5 0.1μf
R4 1.0K
C6 0.1μf
R5 330
C7 .0022μf
R6 2.0K
R7 4.7K
C8 51pf
R8 4.7K
C9 330pf
R9 2.0K
R10 100
C10 0.1μf
C11 0.1μf
R11 330
C12 0.1μf
R12 150
C13 100pf
R13 150
C14 0.1μf
R14 500
C15 0.1μf
C16 0.1μf
R15 1.0K
C17 0.1μf
R16 330
C18 .0022μf
R17 10
R18 10
C19 33μf
C20 3.3μf
HIGHEST COMPONENT DESIGNATION
COMPONENT
SYMBOL NUMBER
R 18
C 20
Z 4
Q 2
CR 11
T 1
NOTES:
1. ALL RESISTORS ARE IN OHMS, 1/4 W, ±5%
2. ALL CAPACITORS ARE TYPES SHOWN BELOW:
TYPE CS13B: C19, C20
TYPE ERIE RED CAP STABLE
C1, C3, C4, C5 C6, C8, C10, C11, C12, C14, C15, C16, C17, C7, C18
TYPE CD6: C2, C8, C9, C13
3. Z3 AND Z4 ARE LOW NOISE NATIONAL SEMICONDUCTORS LM207.
4. TRANSISTOR Q2 2N5056 SHALL BE USED FOR UNIT SERIAL NO'S B195 THRU B200 & B207 THRU B210 ONLY. FOR ALL OTHER UNITS USE TRANSISTOR #2N5057.
LIST OF MATERIALS
DUAL VIDEO AMPLIFIER AND DUAL SAMPLE AND HOLD SCHEMATIC
AEROSPACE RESEARCH INC.
BOSTON, MASS
NEXT ASSY 355-2017
SIZE C
DWG NO. 355-3020
REV. C
SHEET 1 OF 1
REVISIONS
A ECO #547
AJM 12-11-69
B ECO #551
I.S. 12-19-69
C ECO 555
1-6-70
Figure 33



NOTES:

UNLESS OTHERWISE SPECIFIED:

1. ALL DIODES ARE IN914A.
2. ALL TRANSISTORS ARE 2N2369A.
3. ALL RESISTORS ARE IN ⚠ ±1% 1/8W.
4. (B) COMPONENT SYMBOLS R14, C1, & C7 ARE NOT USED

HIGHEST COMPONENT DESIGNATION	
COMPONENT	
SYMBOL	NUMBER
Q	10
R	23
C	14
CR	4

REV	REVISIONS
A	ECO 569
B	ECO 571

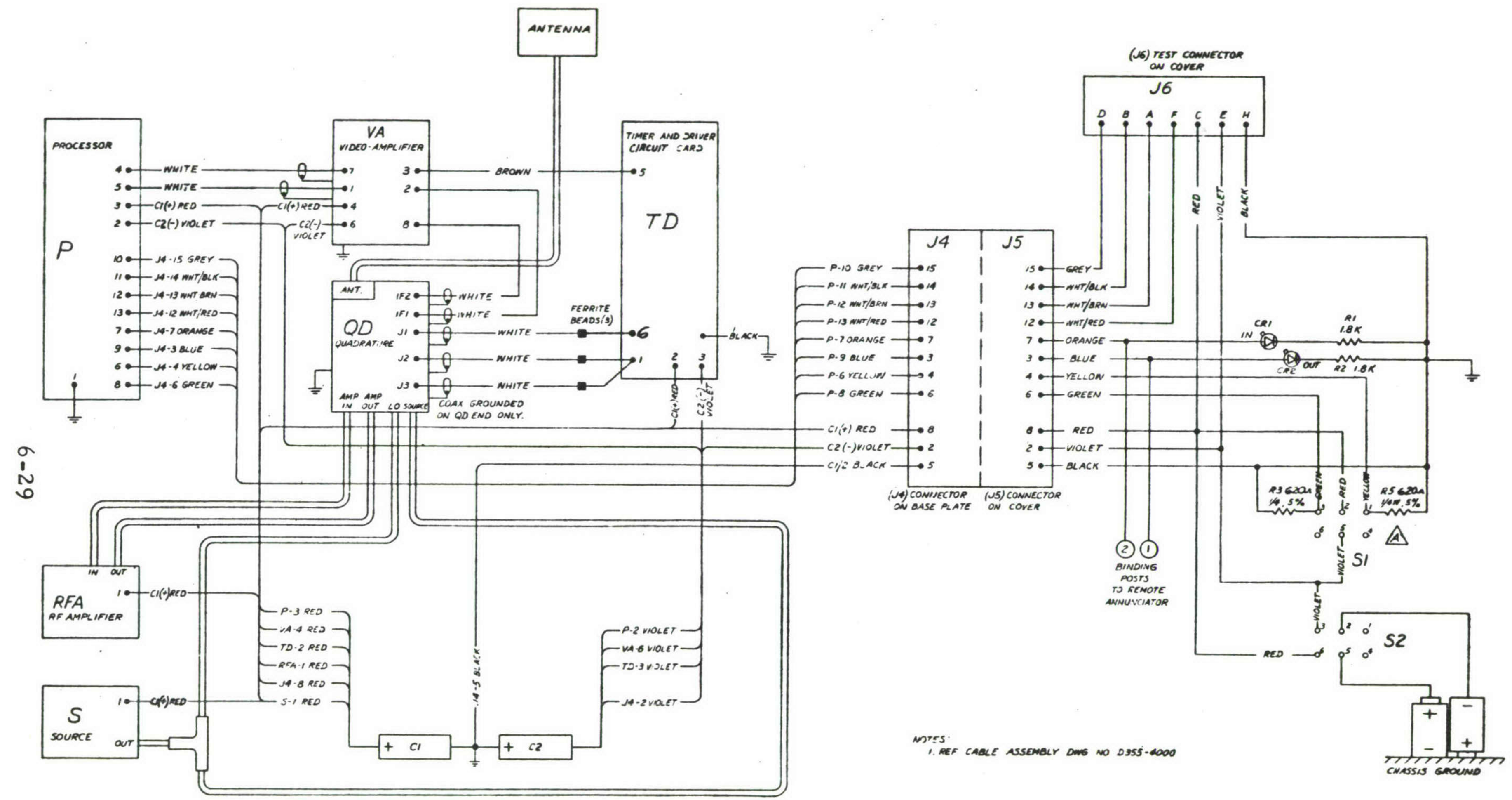
Figure 34

SCHEMATIC,
TIMING AND DRIVING
CIRCUIT

AEROSPACE RESEARCH INC

355-2015

D 355-3019 C



NOTES:
1. REF CABLE ASSEMBLY DWG NO D355-4000

Figure 35

LPSD
INTERCONNECTION
SCHEMATIC

AEROSPACE RESEARCH INC

D 355-3006 A

7.0 OPERATIONAL EVALUATIONS

7.1 FIELD TESTS: FORT HOOD, TEXAS

Three of the Listening Post Surveillance Devices (LPSD's, PPS-14's), produced by Aerospace Research, Inc. for the U.S. Army Land Warfare Laboratory (USALWL), under Contract No. DAAD05-69-C-0279, were made available to Project MASSTER for a scheduled 14-day evaluation at Fort Hood, Texas. The units used were Serial Nos. EA-4, EA-5, and EA-7.

The test site used for baseline data in open terrain was a flat grassy area with a light, widely scattered brush cover. The grass was generally 10 to 15 inches high and untrampled. The foliage site was composed largely of a dense area of broad-leafed foliage mostly brush and trees of low to medium height. The highest trees were 15 to 20 feet, and the lower limbs were generally bent over touching the ground. The site was marked every 20 meters by six-foot wooden stakes dividing the area into a grid pattern. An unpaved road traversed the site diagonally, and the foliage was broken in several places by small clearings. At the front edge of the grid near the paved access road, a large, irregularly shaped clearing was used to accommodate the metro station and the operations vans. The radar was set up at the edge of this clearing looking into the foliage.

For the baseline data, an engineering tape with one-meter markings was employed to designate the target path. The initial path used was down the centerline of the antenna pattern in order to obtain maximum range information for reference to later tests. Single and multiple man targets, both walking and crawling at various speeds, were tried. Several iterations of each target configuration were run in order to measure the consistency of the results. Range information was obtained by ordering the man to halt when the radar operator reported a detection and then reading the range marked on the tape. Control of the test was maintained by placing a radio at each end of the tape and starting and stopping the targets on the command of the radio operator.

Daylight tests at the foliage site were conducted in preparation for four consecutive nights of testing from the 22nd through the 25th of June. For these tests, four observation posts were established looking into the 120 x 120 meter grid square. The radar was used in competition with and also in conjunction with binoculars, starlight scopes, and other night-vision equipment. The night tests were conducted from 2130 to 0500, and about 18 test runs were randomly spaced through the night.

For the tests following the initial baseline measurements, simulated Listening Posts were set up at the edge of the grid square using the same location as the baseline measurements. Several

trails were marked through the foliage using engineering tape, and the unpaved road that ran through the site was also used as a target path.

With seven different paths running at various angles through the site, a more elaborate method of controlling the test was required. For this purpose, a field telephone was installed connecting each Listening Post with the control van, and a signaling system consisting of one ring for a target detection followed by one or two rings for an inbound or outbound target was set up. To control the targets an "aggressor" headquarters was set up at the other side of the grid, in radio contact with the command van. The command van was located just off the access road about 70 meters from, and out of direct sight of, the Listening Posts.

In order to obtain range information for each target run, a set of wooden blocks and a squad radio were issued to the target personnel at "aggressor" headquarters before each run. Each Listening Post (Radar, Starlight Scope, IR) was assigned a different shape block - square, triangle, etc., - and the run number was marked on each block. A complete set of blocks was issued for each run and the man was ordered to drop the shape corresponding to the Listening Post reporting a target detection. At the end of a run, the target personnel would return to "aggressor" headquarters on a path outside of the grid square and report which blocks were dropped.

Each target run was initiated by a radio command from the control van with the target starting at a stake on the edge of the grid square. Starting time, and the time of each target report from the Listening Posts, were recorded. The position of each wooden block dropped on radio command from the control van was measured by a survey team after the completion of the night tests. Weather data and ambient light readings were taken continuously during the test.

Four Listening Posts were set up for the night tests, and the PPS-14 was used in a different one each night. Each night the Listening Post using the LPSD was also equipped with another of the night-vision aids used during the test, and a data collector was assigned to record which instrument reported a sighting first and the time elapsed before the other device reported a sighting.

Tests were moved to an area of high grass for night tests on 26 June and day tests on 29 June. The same test format was maintained.

Several brief tests were conducted during the morning of the 27th. Units EA-4 and EA-7 were operated in close proximity to test for mutual interference; and foliage penetration, with the unit at varying distances from the foliage, was measured. The test schedule was completed on the 30th with the counter-measures tests, and a briefing was conducted for Colonel Wagonner and Major Waring of ACSFOR in the morning, and

a demonstration unit EA-5 was used for battery life tests, for assessing portability and for photographic purposes. This unit was also partially disassembled to evaluate maintainability.

Performance

While the exact ranges and details of performance attained during the tests are at present classified CONFIDENTIAL, all units tested met or surpassed the design range stated in the Operating Manual. In the two weeks of testing, there were no false alarms and the overall probability of detection exceeded 90%. It is, perhaps, important to note that the radars were operated by untrained troops.

Several small problems occurred during the tests. During the evening of the 22nd, the wires leading to the wrist alarm were inadvertently shorted by the operator causing temporary loss (until the shorted lead was bent out of the shorting position) of the alarm signal and resulting in a couple of missed detections. This problem has been alleviated by installation of an insulator between the binding posts on the wrist alarms. Another problem encountered during the tests was an increase in power supply impedance after about six hours of operation of unit EA-4, resulting in a temporary marked decrease in range performance. This first appeared on the evening of the 25th. When the problem again appeared on the 26th, unit EA-4 was replaced during the four-hour balance of the test by EA-7 and the problem was isolated to apparent poor battery-contact pressure. Measures are now being taken to insure that this problem will not recur. No electronic failures were experienced during the tests.

For further information concerning these tests consult "Final Test Report of Listening Post Surveillance Device, LPSD, AN/PPS-14 (MAE) (CONFIDENTIAL)" dated July 1970; From Director, Project MASSTER, Fort Hood, Texas to D.A., Washington, D.C.

7.2 FIELD TESTS: VIETNAM

A ninety-day evaluation was made of the AN/PPS-14 Listening Post Surveillance Device (LPSD) in the Republic of Vietnam during August 1970. Five LPSD's were provided for evaluation. They were Serial Numbers EA-2, -4, -5, -7, and -10. Three of these units were evaluated by the Americal Division and two by the 101st Airborne Division.

Evaluation Schedule

The five LPSD's were made available to the participating units during the first week of August 1970. Three LPSD's, Serial Numbers EA-2, -5, and -7, were delivered to the Americal Division on 2 August 1970 and two LPSD's, Serial Numbers EA-4 and -10, were supplied to the 101st Airborne Division on 5 August 1970. The 101st was able to implement their evaluation plan immediately; however,

due to administrative delays, the Americal Division was not able to commence their evaluation period until 15 August 1970. In both cases, the scheduled period of evaluation was ninety days.

Evaluation Plan

The plan for evaluating the LPSD's at the 101st Airborne Division was to deploy both LPSD's with the 1st Brigade, 2nd of the 502nd Infantry Battalion and for the first half of the evaluation period use them as listening posts at a small fire support base. During the second half of the evaluation, the LPSD's would be carried in the field and used for ambush and night defense positions.

At the Americal Division, the three LPSD's were each deployed with a different battalion of the 198th Infantry Brigade. EA-2 was deployed with the 1st of the 52nd, EA-5 with the 1st of the 6th, and EA-7 with the 5th of the 46th. Each LPSD was moved about within the battalion to allow each infantry company an opportunity to use the equipment. The LPSD's were used for ambush and small unit night defense positions.

Training

Training of personnel in the operation of the LPSD was conducted on a level as close to the ultimate user as possible. Generally, not more than an hour was required to demonstrate the deployment and operation of the equipment and acquaint the personnel with the concept of use. For demonstration purposes the LPSD was set up on the separately supplied tripod, and a short length of field wire was used to connect the wrist alarm. A demonstration was then given of the procedure for placing the equipment in operation and using the internal test function. Where space and terrain limitations allowed, detection of personnel targets was also demonstrated.

At the Americal Division, training for the 1st of the 52nd was given at the level of the infantry squad leader who would, in turn, train the men in his squad to use the equipment. This battalion chose not to carry the separately supplied tripod but to rely on mounting the LPSD on trees and other suitable objects using the GP strap supplied with each unit. Training at the 1st of the 6th and the 5th of the 46th Infantry Battalions was given at the level of the Company Commander because the elements of the units which would be using the equipment were in the field and not easily reached by available transportation. The commanders of the infantry companies then trained their personnel in the use of the equipment. In the area of operation of these units, large trees or other objects suitable for mounting the LPSD were not available, and both units carried the separately supplied tripod.

Because of the 101^{st} Airborne Division's air mobile capability, better transportation facilities were available than those at the Americal Division, and it was possible to reach the personnel in the field who would be operating the equipment. A training class was held at Fire Support Base Maureen for the personnel of the 1^{st} Brigade 2^{nd} of the 502^{nd} Infantry Battalion who would be operating the equipment. Because of the rugged nature of the terrain and the easy availability of trees for mounting the LPSD, this battalion chose not to use the tripod but to rely on the GP strap supplied with the equipment.

Maintenance

Maintenance facilities for the LPSD's being evaluated by the Americal Division and the 101^{st} Airborne were based at Chu Lai, South Vietnam. This location was chosen because the Americal Division, which bases its operations around Chu Lai, had the larger number of LPSD's. While this arrangement facilitated support for the three units at the Americal, it made maintenance of the two LPSD's being evaluated by the 101^{st} Airborne, which bases its operations at Campt Eagle near Hue Phu Bai, a rather formidable and time consuming task.

One of the main difficulties encountered in maintaining the equipment was the erratic nature of the transportation and communication facilities available. The only reliable method of returning the LPSD's for servicing or shipping the equipment back for use was to hand carry the items to and from the units using the equipment. In most cases this accounted for a large fraction of the equipment down time. This became even more of a problem during the last month of the evaluation period. The monsoon weather begins during October in the northern part of South Vietnam, and air transportation and telephone communications deteriorate accordingly.

A graph of the availability of each LPSD during the evaluation period is shown in Figure 36. The solid lines indicate the time each unit was available for use. Interruptions in the solid line indicate the periods in which the equipment was down for maintenance. The dates shown for these periods are from the time the LPSD was reported down until it was returned to the unit using the equipment.

The first report of maintenance problems came from the 101^{st} Airborne on 14 September 1970. They reported that EA-10 was down and a quick visual inspection of the equipment at Camp Eagle revealed that the LPSD had suffered physical damage, probably due to rough handling in the field. It might be pointed out that the unit using EA-4 and EA-10, the 2^{nd} 502^{nd} Infantry Battalion, had changed its location several times during the first half of the evaluation period--being assigned successively to Fire Support Bases Maureen, Barnett, Normandy, and Veghel, and that movement of equipment and supplies by helicopter in the rugged terrain in which the 101^{st} Airborne operates takes its toll in damaged equipment.

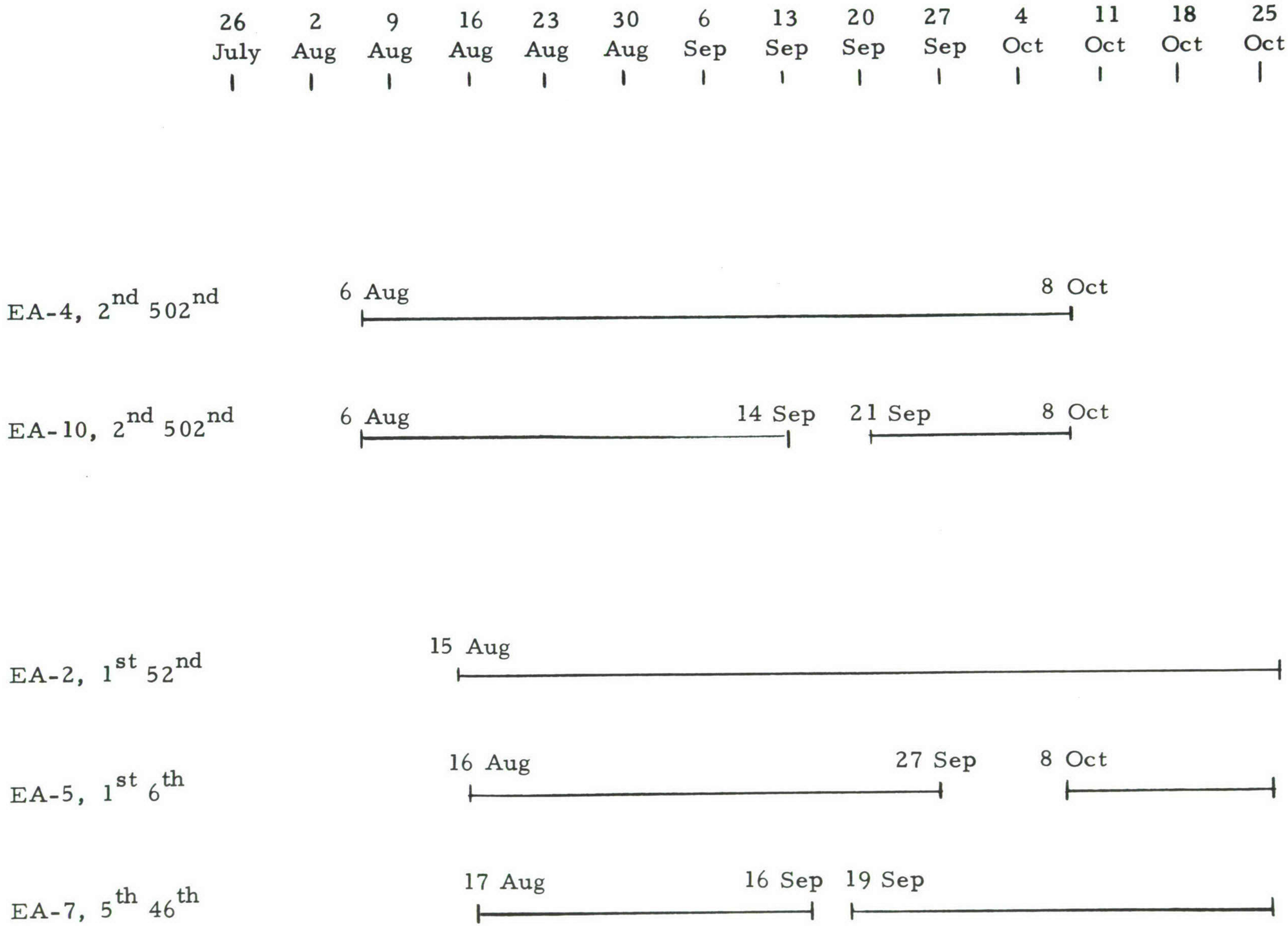


Figure 36: System Availability

EA-10 was returned to Chu Lai for reconditioning on 16 September 1970. The ground connection at the antenna dipole was broken, the test switch on the control panel was inoperative, and the wrist alarm motor no longer functioned. The equipment was repaired, tested, and returned to the 2^{nd} 502^{nd} on 21 September 1970.

The second maintenance problem was reported by the 5^{th} of the 46^{th} on 16 September 1970. Examination of EA-7 revealed that an operational amplifier in the signal processor had failed. The component was replaced and EA-7 was returned to the 5^{th} of the 46^{th} on 19 September 1970.

On 27 September, the 1^{st} of the 6^{th} reported that the LPSD they were using, EA-5, was alarming constantly in the absence of any apparent target and that when the unit was tested against a single walking man, a range of only thirty meters could be obtained and then only for inbound targets. Examination of the unit revealed what appeared to be some form of internal oscillation causing the LPSD to alarm and also driving the automatic gain control to a value which almost completely desensitized the unit. In addition to this, the wrist alarm was not turning on for outbound targets.

After correcting several minor problems such as loose hardware and some questionable ground connections, the oscillation problem still persisted although at a lower level and in a more erratic manner, sometimes allowing the unit to operate almost normally and then suddenly intensifying and causing false alarms and severe loss of sensitivity. Careful examination revealed a poor connection in the positive battery compartment caused by the fact that the battery did not protrude down far enough to make a firm connection with the metal stud at the base of the battery compartment. This problem was corrected by sanding down the insulating material at the bottom of the compartment until proper contact was established. The correction of this problem greatly improved the operation of the system, but some low-level oscillations were still present and would not allow the LPSD to operate at full gain. As a last resort, the RF source was replaced, and this finally corrected the last of the oscillation problems. The difficulty with the outbound alarm circuit was alleviated by modifying the original circuit slightly to provide a time delay, changing the comparator circuit to a monostable multivibrator. EA-5 was returned to the 1^{st} of the 6^{th} on 8 October 1970.

On 8 October 1970, the 101^{st} Airborne reported that both EA-4 and EA-10 were down. Examination of the units at Camp Eagle showed that both LPSD's were exhibiting the same internal oscillation problems that had been observed earlier in EA-5. After a preliminary check of items which had caused problems earlier in EA-5 no improvement was evident, and the two LPSD's were returned to Chu Lai for repair on 10 October. From 10 October until 24 October extensive efforts were made to locate the cause of the oscillations. While some problems in

the signal processor section were found, such as failed operational amplifiers in the automatic gain control circuit of EA-4 and in the automatic frequency control circuit of EA-10, correction of these deficiencies did not eliminate the oscillation. Replacement of the RF source did not improve the situation and other attempted fixes such as large value capacitors to filter out power supply feedback were equally unsuccessful. Time finally ran out on the repair efforts.

Maintenance and support activities at Chu Lai for the LPSD evaluation were terminated on 24 October. Because the Americal Division was not able to commence their evaluation until 15 August, it was decided that the three LPSD's then in operation at the Americal Division would be left in the field until the completion of the evaluation period on 15 November. The two LPSD's which had been used by the 101st Airborne Division and which were down for maintenance at the time were returned to the U.S. Army Land Warfare Laboratory Liaison Officer, Mr. Charles Morgan, at the Army Concept Team in Vietnam office at Long Binh. All other equipment was shipped to the U.S. Army Land Warfare Laboratory, Aberdeen Proving Ground, Maryland.

A final attempt was made at Long Binh to repair one of the two LPSD's with the aid of some newly acquired spare parts which had been sent to Long Binh by airmail. It was possible to reduce the oscillation problem in EA-4 to the point where ranges of 100 meters were attainable with a single walking man as a target, which is somewhat shorter than normal. (Incidentally, it should be noted that the units now being manufactured seem to function reliably at a single-man target range of approximately 140 meters.) This unit was retained at the Army Concept Team in Vietnam office for demonstration purposes. On 26 October, a demonstration was given for Colonel Inskeep, Chief of the ACTIV R&D office, and for General Hume. EA-10 was hand carried back to Aerospace Research, Inc. on 26 October by the technical representative for repair.

User Comments

Several of the units using the LPSD had comments or suggestions for improving certain areas of the design. Both the 2nd of the 502nd and the 1st of the 6th suggested that some method, such as a green indicator light for outbound and a red for incoming targets, be used to easily distinguish indicated target direction in the dark. The 1st of the 6th and the 5th of the 46th, the two units using the separately supplied tripod, both commented that it should be made easier to mount the radar on the tripod and that something should be done about the tripod's susceptibility to dust and dirt jamming the tripod legs. The wrist alarm was very favorably received and was used in preference to the audio indicators supplied by the Land Warfare Laboratory as an alternate means of remoting the alarm.

Operational Results

Operations in the area of the Americal and 101st Airborne Divisions during the evaluation period can probably best be described as "search and evade" and the beginning of the evaluation period also coincided with the end of the Cambodian operations; for these reasons, enemy contact during this period was very light. To date, one confirmed detection has been reported at the Americal Division by the 5th of the 46th resulting in six enemy killed in action. Inquiry among the units using the equipment failed to turn up any cases of a properly functioning LPSD missing targets in its field of view or having a high false-alarm rate. Operator acceptance among infantry personnel with no previous radar experience was very good.

8.0 FINAL ACCEPTANCE TESTS

A method for checking the operational acceptability of AN/PPS-14 Listening Post Surveillance Devices is outlined in Table VI. Two general tests are described, one for checking the unit when no targets are present, and the other when the radar is operating against known targets.

Tests performed on production units shipped on the contract were checked against the criteria shown in Table VI, and the results of these tests are shown in Table VII.

The specifications for circuit tests, and the results of these tests for units shipped are shown in Table VIII.

TABLE VI

LPSD MINIMUM ACCEPTANCE CRITERIA

RADAR OPERATING WITH NO TARGETS

1. Radar in Open Field

   a. AGC ≤ 10 (Less than 3 dB gain suppression)

   b. AFC ≤ 0 (AFC loop not controlling)

   c. Integrator Offset

      (1) Low Channel: Offset < 1/4 Det. Threshold

      (2) High Channel: Offset < 1/4 Det. Threshold

2. Radar in Open Facing Blowing Trees

   a. AGC ≤ 10 (Less than 3 dB gain suppression)

   b. AFC Adapting: Proportional to wind velocity

   c. Integrators

      (1) Average Offset < 1/4 Detection Threshold for High and Low Velocity Channels

      (2) Offset Fluctuations

         (a) Steady Wind < 1/2 Detection Threshold Peak for High and Low Velocity Channels

         (b) Gusts of Wind < 3/4 Detection Threshold Peak for High and Low Velocity Channels

RADAR OPERATION - TARGET DETECTION

1. Upright Walking Man - Open Field

   a. Maximum Range (IN and OUT): 130 meters

   b. Intermediate Sensitivity (High and Low Velocity)

      (1) 50-100 meter range: 6' maximum in radial direction

TABLE VII

LPSD MINIMUM SYSTEM ACCEPTANCE CRITERIA - FIELD TESTS

Unit Ser. No	No Targets										Target Detection						
	Radar Facing Open Field				Rada.		Facing Trees				Upright Walking Man in Open Field						
			Int. Offset				Int. Offset				Audio Alarm					Wrist Alarm	
							Wind < 1/4 Det.		Gust < 3/4 Det.				Intermediate Sensitivity Paces to Alarm-5 max				
	AGC ≤0	AFC ≤5 Light Mod. Wind	Low 1/4 Det. Max.	High 1/4 Det. Max.	AGC ≤0 Except for Gusts	AFC Active & Wind	Low	High	Low	High	IN 130m Min.	OUT 130m Min.	@50m	@75m	@100m	IN 100m Min.	OUT 100m Min.
1	-5	0	x	x	x	x	x	x	x	x	125	140	2	1	2	125	120
2	-5	0	x	x	x	x	x	x	x	x	135	145				120	110
3	-5	0	x	x	x	x	x	x	x	x	125	135	2	2	4	120	100
4	0	7.5	x	x	x	x	x	x	x	x	145	155				140	110
5	0	2.5	x	x	x	x	x	x	x	x	120	130				110	110
6	-5	2.5	x	x	x	x	x	x	x	x	110	135	2	2	3	105	105
7	15	5	x	x	x	x	x	x	x	x	140	140				130	110
10	-5	5	x	x	x	x	x	x	x	x	135	130				135	110

TABLE VIII

LPSD ACCEPTANCE TESTS
CIRCUIT TESTS

Test	Specification Value	Serial Numbers							
		1	2	3	4	5	6	7	10
1. Power									
a. +6 V, Current	125±25 ma	138	137	135		140	140	135	130
b. -6 V, Current	125±25 ma	112	133	115		115	112	110	105
2. Video Amp. Gain									
a. Pin #1	35 ± 1 dB	36	30	36	36	36	35	35	36
b. Pin #2	35 ± 1 dB	36		36	36	36	35	35	36
3. Video Amp. DC Level									
a. Pin #1	± 2 V Max.	5 mV		100 mV		-2 mV			100 mV
b. Pin #7	± 2 V Max.	87 mV		100 mV		-15 mV			100 mV
4. Relative Transmitter Power	60 mV Min.	90 mV	270	100		68	86	86	95
5. Processor Sensitivity									
a. 10 Hz Input	40 V	18		40		12.5	20	20	40
b. 2.5 Hz Input	40 V	18		40		12.5	20	20	40
6. Field Test									
a. Range Incoming	120 m Min.	140	125		125	125	130	130	120
b. Range Outgoing	120 m Min.	140	125		125	130	130	130	140
c. No Clutter AGC	Slightly Pos.								

9.0 CONCLUSIONS AND RECOMMENDATIONS

The AN/PPS-14 Listening Post Surveillance Device satisfied – and in many areas exceeded – the requirements originally established by the U.S. Army Land Warfare Laboratory. In the extensive field tests that took place, the system proved to be a highly effective, easy to use early-warning device. False alarm rates have been low, target-detection reliability has been high and the system can be operated by unskilled personnel with a minimum of training.

Although the eight systems delivered under this contract are initial prototype models, the general reliability, nevertheless, has been good. The only incident that marred this high reliability record was associated with stability problems which developed in some of the radar RF sources during evaluation in Vietnam; the problem has since been corrected.

The radar represents an advanced state-of-the-art device in that it utilizes the latest in balanced adaptive processing to optimally reject an extremely large background of clutter while maintaining high detectability of each low-velocity target. To obtain such effective performance in high clutter it was also necessary to design and build RF and video circuitry that operates at very high levels of stability with wide dynamic range and ultra high linearity.

During the course of the testing of the prototype models, a number of areas for later improvement were found. ARI feels that should these improvements be introduced the utility and effectiveness of the device can be further enhanced at minimal cost in terms of time and engineering effort. The suggested improvements are listed below:

a. The wrist alarm wire connections could be improved by the use of heavy duty push-and-release type connectors similar to those used on field telephones.

b. The battery compartment design could be improved by utilizing a longer-travel spring for making contact to the batteries; this would also reduce the amount of torque needed to install or remove the battery caps.

c. A small battery-condition indicator could be added.

d. Heavier duty securing fasteners could be utilized on the antenna flaps to reduce their tendency to bend with repeated use.

e. The size of the "test" and "operate" switches could be increased to permit easier operation by personnel wearing gloves.

f. The back of the radar case could be formed and ribbed in such a way that the surface can bear against a tree more effectively in those cases when a tripod mount is not used.

g. Two different colors of light emitting diodes could be utilized on the wrist alarm to permit easier identification of incoming or outgoing alarms at night; as an example, green LED's can be used for outgoing and red for incoming.

h. A tripod which is somewhat more rugged, but not heavier, should be considered.

i. Consideration should be given to the possibility of introducing a wireless connection to the wrist alarm to allow the operator total freedom of movement.

j. Some means for allowing the system to be tested from the wrist alarm location could be developed.

k. An accessory battery box to utilize batteries other than the internal mercury cells should be designed for use with the radar during cold weather operation.

l. Voltage regulators should be added to the system to allow continued operation from batteries when their internal impedance has substantially increased due to approaching end of life.

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13. ABSTRACT

The Listening Post Surveillance Device (LPSD), AN/PPS-14, was developed to increase the target acquisition capability of combat riflemen under conditions of poor visibility, such as would be caused by intervening foliage, darkness, and inclement weather.

The development program started first with a shorter range CW radar system, but it rapidly evolved into a Pulsed Doppler system when the performance advantages and growth potential of such a system became apparent. The basic system operates at L-band, and the nucleus of the system is an adaptove and balanced signal processor which enables the radar to cope with a high clutter background while maintaining reliable target-detection performance.

Tests in Boston and Aberdeen as well as operational evaluation at Fort Hood and in Vietnam showed the radar to be an effective device for detecting targets up to 130 meters in open space, and approximately 30 to 100 meters in foliage depending upon density and wind velocity.

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